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APPLICATION

for

UNITED STATES LETTERS PATENT

on

DETECTION AND TREATMENT OF POLYCYSTIC KIDNEY DISEASE

by

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DETECTION AND TREATMENT OF POLYCYSTIC KIDNEY DISEASE

[0001] This application claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Serial No. 60/218,261, filed July 13, 2000, and U.S. Serial No. 60/283,691, filed April 13, 2001, the entire contents of each of which is incorporated herein by reference.

[0002] This invention was made in part with government support under Grant Nos. DK48006, TW05393, and DK02562 awarded by the National Institutes of Health. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0003] The present invention relates generally to the diagnosis and treatment of polycystic kidney disease and more specifically to probes and agents useful in diagnosing and treating polycystic kidney disease and related disorders.

BACKGROUND INFORMATION

[0004] Autosomal dominant polycystic kidney disease (ADPKD), also called adult-onset polycystic kidney disease, is one of the most common hereditary disorders in humans, affecting approximately one individual in a thousand. The prevalence in the United States is greater than 500,000, with 6,000 to 7,000 new cases detected yearly (Striker *et al.*, Am. J. Nephrol. 6:161-164, 1986; Iglesias *et al.*, Am. J. Kid. Dis. 2:630-639, 1983). The disease is considered to be a systemic disorder, characterized by cyst formation in the ductal organs such as kidney, liver, and pancreas, as well as by gastrointestinal, cardiovascular, and musculoskeletal abnormalities, including colonic diverticulitis, berry aneurysms, hernias, and mitral valve prolapse (Gabow *et al.*, Adv. Nephrol. 18:19-32, 1989; Gabow, New Eng. J. Med. 329:332-342, 1993).

[0005] The most prevalent and obvious symptom of ADPKD is the formation of kidney cysts, which result in grossly enlarged kidneys and a decrease in renal-

concentrating ability. In approximately half of ADPKD patients, the disease progresses to end-stage renal disease, and ADPKD is responsible for 4-8% of the renal dialysis and transplantation cases in the United States and Europe (Proc. Eur. Dialysis and Transplant Assn., Robinson and Hawkins, eds., 17:20, 1981).

[0006] Few diagnostics are available for the identification and characterization of mutations of the PKD1 gene, which is located on human chromosome 16. A major factor contributing to the difficulty in identifying and characterizing mutations of the PKD1 gene is that greater than 70% of the length of the PKD1 gene is replicated on chromosome 16 and elsewhere, resulting in at least six PKD1 homologs. Significantly, the PKD1 homologs share a very high sequence identity with the PKD1 gene, including sequences having greater than 95% identity with the PKD1 gene. As such, oligonucleotides that have been examined for use as specific probes, or as primers for amplification, of PKD1 gene sequences have been found to cross-hybridize with the PKD1 homologs, and the inability to identify PKD1 locus specific probes has prevented accurate analysis of PKD1 gene mutations.

[0007] The identification and characterization of PKD1 gene mutations have been further hindered, in part, because transcription of the PKD1 gene results in production of a 14 kilobase (kb) mRNA, which is highly GC-rich. In addition, unlike the remainder of the PKD1 gene, which is extremely compact (approximately 13.5 kb mRNA coded within approximately 30 kb genomic DNA), exon 1 is separated from the rest of the gene by an intron of approximately 19 kb. Thus, previous investigators have simply placed the 5' anchor primer within the first intron and used it as a link to more 3' sequences. Exon 1 has several other features that have been major obstacles to its amplification, including an extremely high GC content (approximately 85%), and the ability to replicate with high fidelity in PKD1 gene homologs. Furthermore, no effective method for DNA based analysis of PKD1 gene exon 22, which is flanked on both ends by introns that contain lengthy polypyrimidine tracts. Accordingly, very few

positions within the replicated segment and flanking exon 22 are suitable for the design of PKD1-specific primers.

[0008] A few oligonucleotides useful for examining regions of the human PKD1 gene, have been described. For example, the primer set forth below as SEQ ID NO:11 has been described in U.S. Pat. No. 6,017,717, and the primer set forth as SEQ ID NO:18 has been described by Watnick *et al.* (Hum. Mol. Genet. 6:1473-1481, 1997). Also, the primers set forth below as SEQ ID NOS:9, 10, 49 to 51, and 61 to 105 have been described by Watnick *et al.* (Am. J. Hum. Genet. 65:1561-1571, 1999). The primers set forth below as SEQ ID NOS: 9 and 10 and SEQ ID NOS: 11 and 12 also were more recently described by Phakdeekitcharoen *et al.* (Kidney International 58:1400-1412, 2000). In addition, a primer set forth as SEQ ID NO:13 in U.S. Pat. No. 6,071,717 has a nucleotide sequence that is substantially identical to that set forth below as SEQ ID NO:10, and a primer designated TWR2 by Watnick *et al.* (Mol. Cell 2:247-251, 1998) has a nucleotide sequence that is substantially identical to that set forth below as SEQ ID NO:12.

[0009] Despite the large number of families having diseases associated with PKD1 gene mutations, the potential clinical and scientific impact of mutation studies, and the availability of a genomic structure, the fact that only a relatively small number of PKD1 mutations have been described demonstrates the relative paucity of data due to the complicated genomic structure of the PKD1 gene. Thus, there exists a need for diagnostic methods suitable for examining the PKD1 gene and for identifying disorders related to PKD1 gene mutations. The present invention satisfies this need and provides additional advantages.

SUMMARY OF THE INVENTION

[0010] The present invention provides compositions and methods that allow for the selective examination of the human PKD1 gene, including the detection and identification of PKD1 gene mutations. For example, the compositions of the invention include oligonucleotide primers that are useful for selectively amplifying a region of a PKD1 gene, but not a corresponding region of a PKD1

homolog. Accordingly, the present invention relates to a PKD1 gene specific primer, which can be one of a primer pair. A primer of the invention includes a 5' region and adjacent PKD1-specific 3' region, wherein the 5' region has a nucleotide sequence that can hybridize to a PKD1 gene sequence and, optionally, to a PKD1 homolog sequence, and the 3' region has a nucleotide sequence that selectively hybridizes only to a PKD1 gene sequence, and particularly not to a PKD1 gene homolog sequence, except that a primer of the invention does not have a sequence as set forth in SEQ ID NO:11, SEQ ID NO:18, SEQ ID NO:52, or SEQ ID NO:60. A 5' region of a primer of the invention generally contains at least about ten contiguous nucleotides, and the 3' region contains at least one 3' terminal nucleotide, wherein the at least one 3' terminal nucleotide is identical to a nucleotide that is 5' and adjacent to the nucleotide sequence of the PKD1 gene to which the 5' region of the primer can hybridize, and is different from a nucleotide that is 5' and adjacent to a nucleotide sequence of the PKD1 homolog to which the 5' region of the primer can hybridize. Generally, the primer includes a 5' region of about 14 to 18 nucleotides and a 3' region of about 2 to 6 nucleotides, particularly about 2 to 4 nucleotides. For example, a primer of the invention can have a sequence as set forth in any of SEQ ID NOS:3 to 10, 12 to 17, 19 to 51 and 61 to 113.

[0011] The present invention also relates to an isolated mutant PKD1 polynucleotide, or an oligonucleotide portion thereof. The polynucleotides of the invention are exemplified by mutation of SEQ ID NO:1, which appear to be normal variants that are not associated with a PKD1-associated disorder, for example, a polynucleotide or oligonucleotide that includes nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; nucleotide 10255, wherein nucleotide 10255 is a T; or a combination thereof; and by mutations of SEQ ID NO:1 that are associated with a PKD1-associated disorder, for example, a polynucleotide or oligonucleotide that includes nucleotide 3110 of SEQ ID NO:1, wherein nucleotide 3110 is a C; nucleotide 8298 of SEQ ID NO:1,

wherein nucleotide 8298 is a G; nucleotide 9164 of SEQ ID NO:1, wherein nucleotide 9164 is a G; nucleotide 9213 of SEQ ID NO:1, wherein nucleotide 9213 is an A; nucleotide 9326 of SEQ ID NO:1, wherein nucleotide 9326 is a T; nucleotide 10064 of SEQ ID NO:1, wherein nucleotide 10064 is an A; or a combination thereof. The invention also provides a vector containing such a polynucleotide, or an oligonucleotide portion thereof, and provides a host cell containing such a polynucleotide or oligonucleotide, or vector.

[0012] A PKD1-specific primer of the invention is exemplified by an oligonucleotide that can selectively hybridize to a nucleotide sequence that flanks and is within about fifty nucleotides of a nucleotide sequence selected from about nucleotides 2043 to 4209; nucleotides 17907 to 22489; nucleotides 22218 to 26363; nucleotides 26246 to 30615; nucleotides 30606 to 33957; nucleotides 36819 to 37140; nucleotides 37329 to 41258; and nucleotides 41508 to 47320 of SEQ ID NO:1. The primer, which can be one of a primer pair, can have a nucleotide sequence substantially identical to any of SEQ ID NOS: 3 to 18, provided that when the primer is not one of a primer pair, the primer does not have a sequence as set forth in SEQ ID NO:11, SEQ ID NO:18, SEQ ID NO:52, or SEQ ID NO:60. Accordingly, the present invention further relates to a primer pair that can amplify a portion of a PKD1 gene, for example, the wild type PKD1 gene set forth as SEQ ID NO:1, wherein the amplification product can include about nucleotides 2043 to 4209; nucleotides 17907 to 22489; nucleotides 22218 to 26363; nucleotides 26246 to 30615; nucleotides 30606 to 33957; nucleotides 36819 to 37140; nucleotides 37329 to 41258; nucleotides 41508 to 47320; or a combination thereof. A primer pair of the invention is useful for performing PKD1-specific amplification of a portion of a PKD1 gene.

[0013] Primer pairs of the invention are exemplified by a pair including at least one forward primer and at least one reverse primer of the oligonucleotides sequences set forth in SEQ ID NOS:3 to 18 or a sequence substantially identical thereto. In one embodiment, the primer pair includes SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11

and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; or SEQ ID NOS:9 and 113. Also provided are primer pairs useful for performing nested amplification of a PKD1-specific amplification product of a PKD1 gene, for example, the primer pairs set forth as SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS: 51 and 61; SEQ ID NOS:62 and 63; SEQ ID NOS:64 and 65; SEQ ID NOS:66 and 67; SEQ ID NOS:68 and 69; SEQ ID NOS:70 and 71; SEQ ID NOS:72 and 73; SEQ ID NOS:74 and 75; SEQ ID NOS:76 and 77; SEQ ID NOS:78 and 79; SEQ ID NOS:80 and 81; SEQ ID NOS:82 and 83; SEQ ID NOS:84 and 85; SEQ ID NOS:86 and 87; SEQ ID NOS:88 and 89; SEQ ID NOS:90 and 91; SEQ ID NOS:92 and 93; SEQ ID NOS:94 and 95; SEQ ID NOS:96 and 113; SEQ ID NOS:97 and 98; SEQ ID NOS:99 and 100; SEQ ID NOS:101 and 102; SEQ ID NOS:103 and 104; SEQ ID NOS: 105 and 106; SEQ ID NOS:107 and 108; SEQ ID NOS:109 and 110; or SEQ ID NOS:111 and 112. In another embodiment, the invention relates to a plurality of primer pairs, which can include two or more primer pairs that are useful for generating two or more PKD1-specific amplification products of a PKD1 gene; or can include two or more primer pairs that are useful for generating a PKD1-specific amplification product of a PKD1 gene and for generating a nested amplification product of the PKD1-specific amplification product.

[0014] The present invention also relates to a purified mutant PKD1 polypeptide, or a peptide portion thereof, comprising an amino acid sequence of a mutant of SEQ ID NO:2. A mutant PKD1 polypeptide, or peptide portion thereof can be substantially identical to a sequence of SEQ ID NO:2 and, for example, include amino acid residue 88 of SEQ ID NO:2, wherein residue 88 is a V; residue 967 of SEQ ID NO:2, wherein residue 967 is an R; residue 2696 of SEQ ID NO:2, wherein residue 2696 is an R; residue 2985 of SEQ ID NO:2, wherein residue 2985 is a G; residue 3039 of SEQ ID NO:2, wherein residue 3039 is a C;

residue 3285 of SEQ ID NO:2, wherein residue 3285 is an I; or residue 3311 of SEQ ID NO:2, wherein residue 3311 is an R; or can include residue 3000 of a truncated mutant PKD1 polypeptide ending at amino acid residue 3000 with respect to SEQ ID NO:2, wherein residue 3001 is absent (and the mutant PKD1 polypeptide is truncated) due to the presence of a STOP codon in the encoding mutant PKD1 polynucleotide; or a combination of such mutations. Also provided is a purified antibody that specifically binds to a mutant PKD1 polypeptide, or to a peptide thereof.

[0015] The present invention further relates to a primer or an oligonucleotide of the invention immobilized to a solid support. In addition, the primer or oligonucleotide can be one of a plurality of primers, oligonucleotides, or a combination thereof, each of which is immobilized to a solid support. The solid support can be any support, including, for example, a microchip, in which case, the primers, oligonucleotides, or combination thereof can be arranged in array, particularly an addressable array. The primers, oligonucleotides, or combination thereof also can be degenerate with respect to each other, and specific for a wild type PKD1 polynucleotide, a mutant PKD1 polynucleotide, including a variant, or combinations thereof, and, therefore, provide a means for multiplex analysis. Accordingly, the present invention provides compositions comprising one or a plurality of immobilized primers or oligonucleotides of the invention, or combinations thereof.

[0016] The present invention also relates to a method of detecting a PKD1 polynucleotide in a sample, wherein the PKD1 polynucleotide is a wild type PKD1 polynucleotide having a sequence as set forth in SEQ ID NO:1, or a mutant PKD1 polynucleotide, which can be a variant PKD1 polynucleotide that has a sequence different from SEQ ID NO:1 but is not associated with a PKD1-associated disorder or can be a mutant PKD1 polynucleotide that is associated with a PKD1-associated disorder. A method of the invention can be performed, for example, by contacting nucleic acid molecules in a sample suspected of containing a PKD1 polynucleotide with at least one primer pair under conditions

suitable for amplification of a PKD1 polynucleotide by the primer pair; and generating a PKD1-specific amplification product under said conditions, thereby detecting a PKD1 polynucleotide in the sample. The primer pair can be any primer pair as disclosed herein, for example, a primer pair such as SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; or SEQ ID NOS:9 and 113; or can be a combination of such primer pairs.

[0017] A method of detecting a PKD1 polynucleotide can further include, upon generating a PKD1-specific amplification product, contacting the amplification product with at least a second primer pair, under conditions suitable for nested amplification of the PKD1-specific amplification product by the second primer pair, and generating a nested amplification product. The second primer pair can be any primer pair that can produce a nested amplification product of the PKD1-specific amplification product, for example, a second primer pair such as SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS:51 and 61; primer pairs formed using consecutive primers set forth in Table 2 as SEQ ID NOS:62 to 96, 113, and 97 to 112; or a combination thereof.

[0018] Upon detecting a PKD1 polynucleotide in a sample according to a method of the invention, an additional step of detecting the presence or absence of a mutation in an amplification product of the PKD1 polynucleotide in the sample as compared to a corresponding nucleotide sequence in SEQ ID NO:1. As such, a method of the invention provides a means to identify a PKD1 polynucleotide in a sample as a mutant PKD1 polynucleotide or a wild type PKD1 polynucleotide, wherein detecting the absence of a mutation in the amplification product identifies the PKD1 polynucleotide in the sample as a wild type PKD1 polynucleotide, and wherein detecting the presence of a mutation in the amplification product

identifies the PKD1 polynucleotide in the sample as a mutant PKD1 polynucleotide, which can be a variant PKD1 polynucleotide, or can be mutant PKD1 polynucleotide associated with a PKD1-associated disorder, the latter of which are exemplified by a polynucleotide that is substantially identical to SEQ ID NO:1, and wherein at least nucleotide 474 is a T; nucleotide 487 is an A; nucleotide 3110 is a C; nucleotide 8298 is a G; nucleotide 9164 is a G; nucleotide 9213 is an A; nucleotide 9326 is a T; nucleotide 9367 is a T; nucleotide 10064 is an A; nucleotide 10143 is a G; nucleotide 10234 is a C; or nucleotide 10255 is a T.

[0019] The presence or absence of a mutation in an amplification product generated according to a method of the invention can be detected any method useful for detecting a mutation. For example, the nucleotide sequence of the amplification product can be determined, and can be compared to the corresponding nucleotide sequence of SEQ ID NO:1. The melting temperature of the amplification product also can be determined, and can be compared to the melting temperature of a corresponding double stranded nucleotide sequence of SEQ ID NO:1. The melting temperature can be determined using a method such as denaturing high performance liquid chromatography.

[0020] An advantage of a method of the invention is that a large number of samples can be examined serially or in parallel. Accordingly, a method of the invention can be performed with respect to a plurality of samples, and can be performed using a high throughput format, for example, by organizing the samples of a plurality of samples in an array such as in an array is on a microchip. The method can further include detecting the presence or absence of a mutation in an amplification product of the samples of the plurality of samples, for example, by determining the melting temperature of the amplification product and comparing it to the melting temperature of a corresponding nucleotide sequence of SEQ ID NO:1 using a method such as denaturing high performance liquid chromatography, or the presence or absence of a mutation can be performed using any method useful for such a purpose, for example, matrix-assisted laser

desorption time of flight mass spectrometry or high throughput conformation-sensitive gel electrophoresis, each of which is readily adaptable to a high throughput analysis format.

[0021] In another embodiment, the presence or absence of a mutation in an amplification product can be detected by contacting the amplification product with the oligonucleotide of the invention, under condition suitable for selective hybridization of the oligonucleotide to an identical nucleotide sequence; and detecting the presence or absence of selective hybridization of the oligonucleotide to the amplification product. Using such a method detecting the presence of selective hybridization identifies the PKD1 polynucleotide in the sample as a mutant PKD1 polynucleotide, and detecting the absence of selective hybridization identifies the PKD1 polynucleotide as a wild type PKD1 polynucleotide. Where an absence of a mutation is detected, the PKD1 polynucleotide in the sample is identified as a wild type PKD1 polynucleotide. In comparison, where the presence of a mutation is identified, the mutant PKD1 polynucleotide so identified can be further examined to determine whether the mutant PKD1 polynucleotide is a variant PKD1 polynucleotide, which is associated with a normal phenotype with respect to PKD1, for example, where the amplification product has a nucleotide sequence substantially identical to SEQ ID NO:1, and including C474T, G487A, G4885A; C6058T; G6195A; T7376C; C7696T; G8021A; C9367T, A10143G, T10234C, or a combination thereof, or is a mutant PKD1 polynucleotide associated with a PKD1-associated disorder, for example, where the amplification product has a nucleotide sequence substantially identical to SEQ ID NO:1, and including T3110C, G3707A; T6078A; C7433T; T8298G; A9164G; G9213A, C9326T; G10064A; an insertion of GCG between nucleotides G7535 and A7536; or a combination thereof, each of which is associated with ADPKD (see Example 2; see, also, Phakdeekitcharoen *et al.*, *Kidney International* 58:1400-1412, 2000, which is incorporated herein by reference).

[0022] The present invention further relates to a method of detecting the presence of a mutant PKD1 polynucleotide in a sample. In one embodiment, a

method of the invention is performed by amplifying a nucleic acid sequence in a sample suspected of containing a mutant PKD1 polynucleotide using a primer pair of the invention, for example, a primer pair selected from SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; or SEQ ID NOS:9 and 113, thereby obtaining a PKD1-specific amplification product of a PKD1 gene sequence; and detecting a mutant PKD1 polynucleotide in the amplification product. The mutant PKD1 nucleotide in the amplification product can be detected using any method useful for detecting a mutation in a polynucleotide, for example, using denaturing high performance liquid chromatograph. In another embodiment, a method of the invention is performed by contacting a sample suspected of containing a mutant PKD1 polynucleotide with a probe comprising an isolated polynucleotide of the invention, or an oligonucleotide portion thereof, under conditions such that the probe selectively hybridizes to a mutant PKD1 polynucleotide, and detecting specific hybridization of the probe and a PKD1 polynucleotide, thereby detecting the presence of a mutant PKD1 polynucleotide sequence in the sample.

[0023] The present invention further relates to a method of identifying a subject having or is at risk of having a PKD1-associated disorder. Such a method can be performed, for example, by contacting nucleic acid molecules in a sample from a subject with at least one primer pair of the invention under conditions suitable for amplification of a PKD1 polynucleotide by the primer pair, thereby generating an amplification product; and testing an amplification product for the presence or absence of a mutation indicative of a PKD1-associated disorder. As disclosed herein, the absence of such a mutation identifies the subject as not having or at risk of the having a PKD1-associated disorder, wherein the presence of such a mutation identifies the subject as having or is at risk of having a PKD1-associated disorder, for example, ADPKD or acquired cystic disease.

[0024] A primer pair useful in a diagnostic method of the invention can include at least one primer pair selected from SEQ ID NO:3 and 4; SEQ ID NO:5 and 6; SEQ

ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; and SEQ ID NOS:9 and 113. The subject can be any subject having a PKD1 gene and susceptible to a PKD1-associated disorder, including a vertebrate subject, and particularly a mammalian subject such as a cat or a human. In addition, the diagnostic method can be performed in a high throughput format, thereby allowing the examination of a large number samples in a cost-effective manner.

[0025] The diagnostic method can further include contacting the amplification product generated as described above with at least a second primer pair, under conditions suitable for nested amplification of the amplification product by a second primer pair, thereby generating a nested amplification product. The second primer pair can be, for example, a primer pair selected from SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS:51 and 61; a primer pair formed using two consecutive primers set forth in Table 2 as SEQ ID NOS:62 to 96, 113, and 97 to 112 (i.e., SEQ ID NOS: 62 and 63, SEQ ID NOS:64 and 65, and so on); and a combination thereof, in which case, the step of testing the amplification product for the presence or absence of a mutation comprises testing the nested amplification product. It should be recognized that the selection of a primer pair for nested amplification is based, in part, on the sequence of the PKD1-specific amplification product that is to be used as a template for the nested amplification, i.e., nested primer pairs are selected such that they can hybridize to a target PKD1-specific amplification product and can amplify the target sequence.

[0026] An amplification product can be tested for the presence or absence of the mutation, for example, by determining the nucleotide sequence of the amplification product, and comparing it to a corresponding nucleotide sequence of SEQ ID NO:1; by determining the melting temperature of the amplification

product, and comparing it to the melting temperature of a corresponding nucleotide sequence of SEQ ID NO:1, for example, using a method such as denaturing high performance liquid chromatography; or by contacting the amplification product with an oligonucleotide probe containing nucleotide 474 of SEQ ID NO:1, wherein nucleotide 474 is a T; nucleotide 487 of SEQ ID NO:1, wherein nucleotide 487 is an A; nucleotide 3110 of SEQ ID NO:1, wherein nucleotide 3110 is a C; nucleotide 8298 of SEQ ID NO:1, wherein nucleotide 8298 is a G; nucleotide 9164 of SEQ ID NO:1, wherein nucleotide 9164 is a G; nucleotide 9213 of SEQ ID NO:1, wherein nucleotide 9213 is an A; nucleotide 9326 of SEQ ID NO:1, wherein nucleotide 9326 is a T; nucleotide 9367 of SEQ ID NO:1, wherein nucleotide 9367 is a T; nucleotide 10064 of SEQ ID NO:1, wherein nucleotide 10064 is an A; nucleotide 10143 of SEQ ID NO:1, wherein nucleotide 10143 is a G; nucleotide 10234 of SEQ ID NO:1, wherein nucleotide 10234 is a C; and nucleotide 10255 of SEQ ID NO:1, wherein nucleotide 10255 is a T, under conditions suitable for selective hybridization of the probe to a mutant PKD1 polypeptide, which can be a normal variant or can be a mutant PKD1 polynucleotide associated with a PKD1-associated disorder.

[0027] The present invention also relates to a method of diagnosing a PKD1-associated disorder in a subject suspected of having a PKD1-associated disorder. Such a method is performed by amplifying a nucleic acid sequence in a sample obtained from the subject using a primer pair suitable for PKD1-specific amplification of a PKD1 gene sequence, for example, a primer pair such as SEQ ID NO:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18, or SEQ ID NOS:9 and 113, thereby obtaining a PKD1-specific first amplification product; and detecting a mutation of a PKD1 gene sequence in the PKD1-specific first amplification product, wherein the mutation is indicative of a PKD1-associated disorder, thereby diagnosing a PKD1-associated disorder in the subject.

[0028] In one embodiment, the diagnostic method includes a step of further amplifying the first amplification product using a second set of primer pairs to obtain a nested amplification product; and detecting a PKD1 gene mutation in the nested amplification product. The second set of primer pairs can be any primer pairs useful for amplifying the PKD1-specific first amplification product, including, for example, the primer pairs exemplified by SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS:51 and 61; or any of the primer pairs formed using consecutive primers set forth in Table 2 as SEQ ID NOS:62 to 96, 113, and 97 to 112.

[0029] In another method, the diagnostic method includes a step of contacting the PKD1-specific first amplification product or second amplification product with a probe comprising an isolated polynucleotide, or an oligonucleotide portion thereof, comprising a mutant of SEQ ID NO:1, under conditions such that the probe can selectively hybridize to a mutant PKD1 polynucleotide; and detecting selective hybridization of the probe to the first amplification product, thereby diagnosing a PKD1-associated disorder in the subject. The probe can be, for example, an oligonucleotide portion of SEQ ID NO:1 that includes one or more of nucleotide 474 is a T; nucleotide 487 is an A; nucleotide 3110 is a C; nucleotide 8298 is a G; nucleotide 9164 is a G; nucleotide 9213 is an A; nucleotide 9326 is a T; nucleotide 9367 is a T; nucleotide 10064 is an A; nucleotide 10143 is a G; nucleotide 10234 is a C; or nucleotide 10255 is a T.

[0030] The present invention also relates to a method of detecting the presence of a mutant PKD1 polypeptide in a sample. Such a method can be performed, for example, by contacting a sample suspected of containing a mutant PKD1 polypeptide with an antibody that specifically binds to a mutant PKD1 polypeptide, under conditions which allow the antibody to bind to the mutant

PKD1 polypeptide and detecting specific binding of the antibody and the mutant PKD1 polypeptide in the sample. The detection of an immunocomplex of the antibody and a mutant PKD1 polypeptide, for example, indicates the presence of a mutant PKD1 polypeptide in the sample. In one embodiment, the method is performed by contacting a tissue sample from a subject suspected of containing a PKD1 polypeptide with the antibody that specifically binds a mutant PKD1 polypeptide under conditions that allow the antibody interact with a PKD1 polypeptide and detecting specific binding of the antibody and the PKD1 polypeptide in the tissue.

[0031] The present invention further relates to a kit for detecting a mutant PKD1 polynucleotide, which can be a variant PKD1 polynucleotide or a mutant PKD1 polynucleotide associated with a PKD1-associated disorder. The kit can contain, for example, a carrier means containing therein one or more containers wherein a first container contains a nucleotide sequence useful for detecting a wild type or mutant PKD1 polynucleotide. As such, a nucleotide sequence useful in a kit of the invention can be an oligonucleotide comprising at least ten contiguous nucleotides of SEQ ID NO:1, including at least one of nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; a position corresponding to nucleotide 3336, wherein nucleotide 3336 is deleted; nucleotide 3707, wherein nucleotide 3707 is an A; nucleotide 4168, wherein nucleotide 4168 is a T; nucleotide 4885, wherein nucleotide 4885 is an A; nucleotide 5168, wherein nucleotide 5168 is a T; nucleotide 6058, wherein nucleotide 6058 is a T; nucleotide 6078, wherein nucleotide 6078 is an A; nucleotide 6089, wherein nucleotide 6089 is a T; nucleotide 6195, wherein nucleotide 6195 is an A; nucleotide 6326, wherein nucleotide 6326 is a T; a position corresponding to nucleotides 7205 to 7211, wherein nucleotides 7205 to 7211 are deleted; nucleotide 7376, wherein nucleotide 7376 is a C; a nucleotide sequence corresponding to nucleotides 7535 to 7536, wherein a GCG nucleotide sequence is inserted between nucleotides 7535 and 7536; nucleotide 7415, wherein nucleotide 7415 is a T; nucleotide 7433, wherein nucleotide 7433 is a T;

nucleotide 7696, wherein nucleotide 7696 is a T; nucleotide 7883, wherein nucleotide 7883 is a T; nucleotide 8021, wherein nucleotide 8021 is an A; a nucleotide sequence corresponding to nucleotide 8159 to 8160, wherein nucleotides 8159 to 8160 are deleted; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; or nucleotide 10255, wherein nucleotide 10255 is a T. A nucleotide sequence useful in a kit of the invention also can comprise one or both primers of a primer pair, particularly at least a forward primer and a reverse primer as set forth in SEQ ID NOS: 3 to 18; and the kit can further include at least a second primer pair, including a forward and reverse primer as set forth in SEQ ID NOS: 19 to 51 and 61 to 113. In another aspect, the present invention relates to a kit containing an antibody that specifically binds to a mutant PKD1 polypeptide or peptide portion thereof.

BRIEF DESCRIPTION OF THE FIGURES

[0032] Figure 1 is a schematic showing the genomic structure of the PKD1 gene (SEQ ID NO:1) and the relative position of locus-specific templates and primers.

[0033] Figure 2 shows the relative position of the BPF6-BPR6 long-range PCR template and the much shorter PKD1-specific exon 28 product, 28F-BPR6. The dashed line below exon 28 identified the long range PCR amplification product that resulted when BPF6, the sequence of which is common to the PKD1 gene and to the homologs, was used in combination with the homolog-specific primer, BPR6HG.

DETAILED DESCRIPTION OF THE INVENTION

[0034] The present invention provides compositions and methods for identifying polycystic kidney disease-associated protein-1 (PKD1) gene variants and mutants, and for diagnosing PKD1-associated disorders in a subject. Prior to

[0035] Autosomal dominant polycystic kidney disease (ADPKD) exhibits a transmission pattern typical of autosomal dominant inheritance, where typically each offspring of an affected individual has a 50% chance of inheriting the causative gene. Linkage studies indicated that a causative gene is present on the short arm of chromosome 16, near the α globin cluster; this locus was designated PKD1 (Reeders *et al.*, Nature, 317:542, 1985.) Though other PKD-associated genes exist (for example, PKD2), defects in PKD1 appear to cause ADPKD in about 85-90% of affected families (Parfrey *et al.*, New Eng. J. Med. 323:1085-1090, 1990; Peters *et al.*, Contrib. Nephrol. 97:128-139, 1992).

[0037] The genomic structure of the PKD1 gene, which is illustrated in Figure 1 (SEQ ID NO:1; see Appendix A; see, also, GenBank Accession No. L39891, which is incorporated herein by reference), extends over approximately 50 kb, contains 46

exons, and is bisected by two large polypyrimidine tracts of approximately 2.5 kb and 0.5 kb, respectively, in introns 21 and 22 (indicated by "...CCTCCTCCT..." in Figure 1). The replicated portion of the gene, which begins prior to the 5'UTR and is believed to end in exon 34 (Figure 1; stippled region), covers approximately two thirds of the 5' end of the gene and is duplicated several times in a highly similar, transcribed fashion elsewhere in the human genome (Germino *et al.*, Genomics 13:144-151, 1992; European Chromosome 16 Tuberous Sclerosis Consortium, 1993, Cell 75:1305-1315). The encoded PKD1 polypeptide is shown as SEQ ID NO:2 (see Appendix A; see, also, GenBank Accession No. P98161, which is incorporated herein by reference). It should be recognized that SEQ ID NO:2 is not the same amino acid sequence as that shown to be encoded by GenBank Accession No. L39891 (see, also, GenBank AAB59488), presumably due to errors in predicting the encoded PKD1 polypeptide from the PKD1 gene sequence. Instead, the wild type PKD1 polypeptide sequence is shown in SEQ ID NO:2 (GenBank Accession No. P98161).

[0038] The present invention provides a PKD1 gene specific primer, which can be one of a primer pair. A primer of the invention includes a 5' region and adjacent PKD1-specific 3' region, wherein the 5' region has a nucleotide sequence that can hybridize to a PKD1 gene sequence or to a PKD1 gene sequence and a PKD1 gene homolog sequence, and the 3' region has a nucleotide sequence that selectively hybridizes only to a PKD1 gene sequence, and particularly not to a PKD1 gene homolog sequence, except that a primer of the invention does not have a sequence as set forth in SEQ ID NO:11, SEQ ID NO:18, SEQ ID NO:52, or SEQ ID NO:60. Thus, a primer of the invention can have a sequence as set forth in any of SEQ ID NOS:3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112 and 113, as well as a sequence that is substantially identical to any of SEQ ID NOS:3 to 51 and 61 to 113, provided the sequence comprises a 5' region that can hybridize to a PKD1 gene

sequence or to a PKD1 gene sequence and a PKD1 gene homolog sequence, and a 3' region that selectively hybridizes to a PKD1 gene sequence, but not to a PKD1 gene homolog sequence; and provided the sequence is not otherwise specifically excluded herein.

[0039] As disclosed herein, a primer of the invention can be prepared by aligning SEQ ID NO:1 with the PKD1 gene homologs contained in GenBank Accession Nos. AC002039, AC010488, AC040158, AF320593 and AF320594 (each of which is incorporated herein by reference; see, also, Bogdanova et al., *Genomics* 74:333-341, 2001, which is incorporated herein by reference) and identifying regions having potential sequence differences, then selecting as PKD1-specific primers those sequences that match over at least about ten nucleotides and that have a mismatch at or adjacent to the 3' terminus of the matched regions (see Example 1; see, also, Phakdeekitcharoen et al., *supra*, 2000). Such primers are referred to as "PKD1-specific primers" because, while they can hybridize to a PKD1 gene and a PKD1 gene homologue, an extension product only can be generated upon hybridization to a PKD1 gene due to the mismatch of one or more nucleotides in the 3' region when the primer hybridizes to a PKD1 gene homologue. Confirmation that a selected oligonucleotide is a PKD1-specific primer can be made using methods as disclosed herein (Example 1) or otherwise known in the art. For example, a simple and straightforward method for determining that a primer is a PKD1-specific primer of the invention is to perform a primer extension or an amplification reaction using the putative PKD1-specific primer and templates including a PKD1 gene sequence and PKD1 gene homolog sequences, and detecting a single extension product or amplification product generated from the PKD1 gene template, but not the PKD1 gene homolog templates. Sequences identified as PKD1-specific primers using this or another method can be confirmed by performing various control experiments as described by Watnick et al. (*supra*, 1999), for example, by comparing an amplification product obtained in a cell having a PKD1 gene with the products, if any, produced using the radiation hybrid cell line, 145.19, which lacks the PKD1 gene but contains PKD1 gene homologs.

[0040] A nucleotide sequence suspected of being useful as a PKD1-specific primer also can be compared against a human genomic DNA database using, for example, a BLAST search or other algorithm, to confirm that the nucleotide sequence meets the requirements of a PKD1-specific primer as defined herein. For example, a putative PKD1-specific primer can be examined at the National Center for Biotechnology Information (NCBI), which can be accessed on the world wide web, by selecting the "Blast" option, thereafter selecting the "Search for short nearly exact matches," entering in the sequence to be examined, and, using the default search algorithms (word size 7), searching the "nr" database, which include all non-redundant GenBank+EMBL+DDBJ+PDB sequences, but no EST, SST, GSS or HTGS sequences; output can be restricted to showing only the top ten matches.

[0041] In a PKD1-specific primer of the invention, the 5' region contains at least about ten contiguous nucleotides, generally at least about 12 nucleotides, and usually about 14 to 18 nucleotides. In addition, the 3' region of the primer contains at least one 3' terminal nucleotide, and can include a sequence of at least about 2 to 6 nucleotides, particularly about 2 to 4 nucleotides. Where the 3' region consists of a single 3' terminal nucleotide, the primer is selected such that the 3' terminal nucleotide is identical to a nucleotide that is 5' and adjacent to the nucleotide sequence of the PKD1 gene to which the 5' region of the primer can hybridize, and is different from a nucleotide that is 5' and adjacent to a nucleotide sequence of the PKD1 homolog to which the 5' region of the primer can hybridize, i.e., provides a mismatched nucleotide. Where the 3' region of the PKD1-specific primer contains two or more nucleotides, one or more of the nucleotides can be mismatched, and the mismatched nucleotide can, but need not include the 3' terminal nucleotide, provided that when the mismatched nucleotide or nucleotides do not include the 3' terminal nucleotide, the primer cannot be extended when hybridized to a PKD1 gene homolog.

[0042] PKD1-specific primers of the invention are exemplified by primers that can selectively hybridize to a nucleotide sequence that flanks and is within about fifty nucleotides of a nucleotide sequence of SEQ ID NO:1 selected from about nucleotides 2043 to 4209; nucleotides 17907 to 22489; nucleotides 22218 to 26363; nucleotides 26246 to 30615; nucleotides 30606 to 33957; nucleotides 36819 to 37140; nucleotides 37329 to 41258; and nucleotides 41508 to 47320. A primer of the invention is exemplified by any of SEQ ID NOS: 3 to 10, 12 to 17, 19 to 51, and 61 to 113, and can have a sequence substantially identical to any of SEQ ID NOS:3 to 51 and 61 to 113, provided the sequence meets the requirements of a PKD1-specific primer as disclosed herein, and provided the sequence is not a sequence as set forth in any of SEQ ID NO:11, SEQ ID NO:18, SEQ ID NO:52, and SEQ ID NO:60.

[0043] A primer is considered to be "substantially identical" to any of SEQ ID NOS:3 to 51 and 61 to 113 if the primer has at least about 80% or 85%, generally at least about 90%, usually at least about 95%, and particularly at least about 99% sequence identity with one of SEQ ID NOS:3 to 51 and 61 to 113, and has a 5' region and adjacent PKD1-specific 3' region, wherein the 5' region has a nucleotide sequence that can hybridize to a PKD1 gene sequence or to a PKD1 gene sequence and a PKD1 gene homolog sequence, and the 3' region has a nucleotide sequence that selectively hybridizes only to a PKD1 gene sequence, and particularly not to a PKD1 gene homolog sequence, as defined herein, except that a primer of the invention does not have a sequence as set forth in SEQ ID NO:11, SEQ ID NO:18, SEQ ID NO:52, or SEQ ID NO:60. As such, a primer of the invention can include one or a few, but no more than about four or five, more or fewer nucleotide than a primer as set forth in SEQ ID NOS:3 to 51 and 61 to 113, provided the primer meets the functional requirements as defined herein.

[0044] The present invention also provides primer pairs. In one embodiment, a primer pair of the invention comprising a forward and reverse PKD1-specific primer as disclosed herein. As such, a primer pair of the invention can amplify a portion of SEQ ID NO:1 including about nucleotides 2043 to 4209;

nucleotides 17907 to 22489; nucleotides 22218 to 26363; nucleotides 26246 to 30615; nucleotides 30606 to 33957; nucleotides 36819 to 37140; nucleotides 37329 to 41258; nucleotides 41508 to 47320; or a combination thereof. In general, a primer pair of the invention can produce an amplification product of about ten kilobases or shorter, generally about 7500 bases or shorter, and particularly about six kilobases or shorter. Primer pairs of the invention are exemplified by a forward primer and a reverse primer selected from SEQ ID NOS:3 to 18, for example, by any of SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; and SEQ ID NOS:9 and 113, which can be used to produce PKD1-specific amplification products of about 0.3 kilobases to about 5.8 kilobases.

[0045] As disclosed herein, a set of eight polymerase chain reaction (PCR) primer pairs can be used to prepare PKD1-specific amplification products that encompass all of the exons and their flanking introns within the replicated region of the PKD1 gene. In view of the disclosed nucleotide sequences of the primers and of SEQ ID NO:1, it will be recognized that additional PCR primer pairs useful for a preparing PKD1-specific first amplification product can be based on the exemplified primers and primer pairs, but can include one or few additional nucleotides (based on SEQ ID NO:1) at one or both ends of the exemplified primers, or can have one or a few nucleotides of an exemplified primer deleted, and their usefulness can be determined by comparing an amplification product generated using the derived or modified primer with a PKD1-specific amplification product as disclosed herein. As such, a primer pair based, for example, on SEQ ID NOS: 3 and 4 can be used to generate a PKD-1 specific amplification product containing about nucleotides 2043 to 4209 of SEQ ID NO:2, where in reference to "about" nucleotides 2043 to 4209 of SEQ ID NO:2 accounts for the disclosure that a primer pair used for amplification can be identical or substantially identical to SEQ ID NOS: 3 and 4.

[0046] Accordingly, the present invention provides primer pairs comprising a forward primer and a reverse primer having nucleotide sequences as set forth in SEQ

ID NOS:3 to 18; primer pairs exemplified by SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; and SEQ ID NOS:9 and 113; and substantially identical primer pairs that comprise primers based on or derived from the exemplified primers, such primer pairs being useful for preparing a PKD1-specific amplification product. The primer pairs shown as SEQ ID NOS: 9 and 10 and SEQ ID NOS: 11 and 12 have been described by Phakdeekitcharoen *et al.* (*supra*, 2000), as have the PKD1 specific amplification products generated using these primers.

[0047] It should be recognized that certain primers and certain primer pairs exemplified herein are not considered to be encompassed within the present invention. For example, the primer set forth in SEQ ID NO:11 has been described in U.S. Pat. No. 6,017,717 (which is incorporated herein by reference; column 24, SEQ ID NO:15); and the primer set forth in SEQ ID NO:18 has been described by Watnick *et al.* (Hum. Mol. Genet. 6:1473-1481, 1997, which is incorporated herein by reference; see page 1479; KG8R25), and, therefore, neither of these primers is considered to be a primer of the invention. Nevertheless, the primers set forth as SEQ ID NOS: 11 and 18 can be encompassed within the primer pairs of the invention, including within various disclosed and exemplified primer pairs, for example, the primer pairs set forth as SEQ ID NOS:11 and 12 and as SEQ ID NOS:17 and 18, as well as within combinations of two or more primer pairs, for example, a combination comprising SEQ ID NOS:11 and 12 and SEQ ID NOS:13 and 14.

[0048] The primers set forth in SEQ ID NO:9 and SEQ ID NO:10 have been described by Watnick *et al.* (Am. J. Hum. Genet. 65:1561-1571, 1999, which is incorporated herein by reference) and, therefore, can be specifically excluded from certain embodiments of the invention, as desired, for example, as encompassed within the primers of the invention. It should be recognized, however, that the combination of SEQ ID NOS:9 and 10 as a primer pair is not described by Watnick *et al.* (*supra*, 1999). SEQ ID NOS:49 to 51 and 61 to 105 also have been described

by Watnick *et al.* (*supra*, 1999) and, therefore, can be specifically excluded from certain embodiments of the invention, as desired.

[0049] Except as provided herein, a primer of the invention is exemplified by any of SEQ ID NOS:3 to 51 and 61 to 113, as well as substantially identical oligonucleotide primers that are based on or derived from SEQ ID NOS:3 to 51 and 61 to 113. It should be recognized, however, that the primer set forth as SEQ ID NO:12 is substantially similar to the primer designated TWR2 by Watnick *et al.* (Mol. Cell 2:247-251, 1998, which is incorporated herein by reference; page 250; 5'-GCAGGGTGAGCAGGTGGGGCCATCCTA-3'; SEQ ID NO:60), and that the primer set forth as SEQ ID NO:10 is substantially identical to SEQ ID NO:13 in U.S. Pat. No. 6,071,717 (5'-AGGTCAACGTGGGCCTCCAAGTAGT-3'; SEQ ID NO:52). As such, a primer having the nucleotide sequence of SEQ ID NO:52 or of SEQ ID NO:60 is specifically excluded from the primers that otherwise would be encompassed within the scope of primers that have a sequence substantially identical to the sequence of the primer set forth as SEQ ID NO:12 or SEQ ID NO:10, respectively.

[0050] The present invention also provides an isolated mutant PKD1 polynucleotide, or an oligonucleotide portion thereof comprising a mutation as disclosed herein. As used herein, the term "isolated" or "purified," when used in reference to a polynucleotide, oligonucleotide, or polypeptide, means that the material is in a form other than that in which it normally is found in nature. Thus, where a polynucleotide or polypeptide occurs in a cell in nature, an isolated polynucleotide or purified polypeptide can be one that separated, at least in part, from the materials with which it is normally associated. In general, an isolated polynucleotide or a purified polypeptide is present in a form in which it constitutes at least about 5 to 10% of a composition, usually 20% to 50% of a composition, particularly about 50% to 75% of a composition, and preferably about 90% to 95% or more of a composition. Methods for isolating a polynucleotide or polypeptide are well known and routine in the art.

[0051] As part of or following isolation, a polynucleotide can be joined to other polynucleotides, such as DNA molecules, for example, for mutagenesis studies, to form fusion proteins, or for propagation or expression of the polynucleotide in a host. The isolated polynucleotides, alone or joined to other polynucleotides, such as vectors, can be introduced into host cells, in culture or in whole organisms. Such polynucleotides, when introduced into host cells in culture or in whole organisms, nevertheless are considered "isolated" because they are not in a form in which they exist in nature. Similarly, the polynucleotides, oligonucleotides, and polypeptides can be present in a composition such as a media formulation (solutions for introduction of polynucleotides, oligonucleotides, or polypeptides, for example, into cells or compositions or solutions for chemical or enzymatic reactions which are not naturally occurring compositions) and, therein remain isolated polynucleotides, oligonucleotides, or polypeptides within the meaning of that term as it is employed herein. An isolated polynucleotide can be a polynucleotide that is not immediately contiguous with nucleotide sequences with which it is immediately contiguous in a genome or other naturally occurring cellular DNA molecule in nature. Thus, a recombinant polynucleotide, which can comprise a polynucleotide incorporated into a vector, an autonomously replicating plasmid, or a virus; or into the genomic DNA of a prokaryote or eukaryote, which does not normally express a PKD1 polypeptide.

[0052] As used herein, the term "polynucleotide" or "oligonucleotide" or "nucleotide sequence" or the like refers to a polymer of two or more nucleotides or nucleotide analogs. The polynucleotide can be a ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) molecule, and can be single stranded or double stranded DNA or RNA, or a double stranded DNA:RNA hybrid. A polynucleotide or oligonucleotide can contain one or more modified bases, for example, inosine or a tritylated base. The bonds linking the nucleotides in a polymer generally are phosphodiester bonds, but can be other bonds routinely used to link nucleotides including, for example, phosphorothioate bonds, thioester bonds, and the like. A polynucleotide also can be a chemically, enzymatically or metabolically modified form.

[0053] As used herein, the term "mutant PKD1 polynucleotide" means a nucleotide sequence that has one or a few nucleotide changes as compared to the nucleotide sequence set forth as SEQ ID NO:1. The nucleotide change can be a deletion, insertion or substitution, and can be silent such that there is no change in the reading frame of a polypeptide encoded by the PKD1 polynucleotide, or can be a change that results in an amino acid change or in the introduction of a STOP codon into the polynucleotide, or a change in a nucleotide sequence involved in transcription or translation of the PKD1 polynucleotide, for example, a change that results in altered splicing of a PKD1 gene transcript into an mRNA (see Example 2). As disclosed herein, a mutant PKD1 polynucleotide can be a polymorphic variant, which, other than one or a few nucleotide changes with respect to SEQ ID NO:1, encodes a PKD1 polypeptide and does not correlate with a PKD1 associated disorder, particularly ADPKD, or can be a mutant PKD1 polynucleotide that contains one or more mutations that correlate with a PKD1 associated disorder such as ADPKD (see Example 2).

[0054] For convenience of discussion and for use as a frame of reference, the PKD1 nucleotide sequence set forth in SEQ ID NO:1 is referred to as a "wild type PKD1 polynucleotide" or a "wild type PKD1 gene" sequence, and, similarly, the polypeptide set forth as SEQ ID NO:2 is referred to as a "wild type PKD1 polypeptide." However, while the presence of the wild type PKD1 gene sequence (i.e., SEQ ID NO:1) in an individual correlates to the absence of ADPKD in the individual, it should be recognized that polymorphic variants of SEQ ID NO:1 also are found in individuals that do not exhibit ADPKD or other PKD1-associated disorder. The term "variants" or "polymorphic variants" is used herein to refer to mutant PKD1 polynucleotide sequences (with respect to SEQ ID NO:1) that do not correlate with the signs or symptoms characteristic of a PKD1 associated disorder such as ADPKD. Variant PKD1 polynucleotides include, for example, nucleotide substitutions that do not result in a change in the encoded amino acid, i.e., silent mutations, such as G4885A, in which the wild type and mutant codons both encode a threonine (T1558T), and C6058T, in which the wild type and mutant codons both

encode a serine (S1949S; see Example 2; see, also, Phakdeekitcharoen *et al.*, *supra*, 2000); those that do not segregate with the disease, or those that are found in a panel of unaffected individuals. As such, it should be recognized that the term "mutant PKD1 polynucleotide" broadly encompasses PKD1 variants, which do not correlate with a PKD1 associated disorder, as well as mutant PKD1 polynucleotides that correlate or are associated with a PKD1 associated disorder.

[0055] Examples of mutant PKD1 polynucleotide sequences, including variant PKD1 polynucleotide sequence, include sequences substantially as set forth in SEQ ID NO:1, but having a mutation at nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; a position corresponding to nucleotide 3336, wherein nucleotide 3336 is deleted; nucleotide 3707, wherein nucleotide 3707 is an A; nucleotide 4168, wherein nucleotide 4168 is a T; nucleotide 4885, wherein nucleotide 4885 is an A; nucleotide 5168, wherein nucleotide 5168 is a T; nucleotide 6058, wherein nucleotide 6058 is a T; nucleotide 6078, wherein nucleotide 6078 is an A; nucleotide 6089, wherein nucleotide 6089 is a T; nucleotide 6195, wherein nucleotide 6195 is an A; nucleotide 6326, wherein nucleotide 6326 is a T; a position corresponding to nucleotides 7205 to 7211, wherein nucleotides 7205 to 7211 are deleted; nucleotide 7376, wherein nucleotide 7376 is a C; a nucleotide sequence corresponding to nucleotides 7535 to 7536, wherein a GCG nucleotide sequence is inserted between nucleotides 7535 and 7536; nucleotide 7415, wherein nucleotide 7415 is a T; nucleotide 7433, wherein nucleotide 7433 is a T; nucleotide 7696, wherein nucleotide 7696 is a T; nucleotide 7883, wherein nucleotide 7883 is a T; nucleotide 8021, wherein nucleotide 8021 is an A; a nucleotide sequence corresponding to nucleotide 8159 to 8160, wherein nucleotides 8159 to 8160 are deleted; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; or

nucleotide 10255, wherein nucleotide 10255 is a T; or a combination thereof (see Example 2; see, also, Tables 3 and 4). Examples of a mutant PKD1 polynucleotide of the invention also include a polynucleotide that encodes a PKD1 polypeptide having substantially as set forth in SEQ ID NO:2, but having an A88V, W967R, G1166S; V1956E; R1995H; R2408C; D2604N; L2696R, R2985G, R3039C, V3285I, H3311R mutation, or a combination thereof, as well as polypeptides that have, for example, an addition of a Gly residue between amino acid residues 2441 and 2442 of SEQ ID NO:2 due to an insertion, or that terminate with amino acid 3000 of SEQ ID NO:2 due to the presence of a STOP codon at the position in SEQ ID NO:1 that would otherwise encode amino acid 3001 (see, also, Table 4; Example 2).

[0056] Additional examples of mutant PKD1 polynucleotides of the invention include polynucleotide sequences that selectively hybridize to the complements of the polynucleotide sequences, or oligonucleotide portions thereof, as disclosed herein, under highly stringent hybridization conditions, *e.g.*, hybridization to filter-bound DNA in 0.5M NaHPO₄, 7% sodium dodecyl sulfate (SDS), 1 mM EDTA at 65°C, and washing in 0.1 x SSC/0.1% SDS at 68°C (Ausubel *et al.*, Current Protocols in Molecular Biology, (Green Publishing Associates, Inc., and John Wiley & Sons, Inc., New York 1989), and supplements; see p. 2.10.3; Sambrook *et al.*, Molecular Cloning: A laboratory manual (Cold Spring Harbor Laboratory Press, 1989), which are incorporated herein by reference), as well as polynucleotides that encode a PKD1 polypeptide substantially as set forth in SEQ ID NO:2, but having one or more mutations; or an RNA corresponding to such a polynucleotide.

[0057] A polynucleotide or polypeptide sequence that is "substantially identical" to a PKD1 polynucleotide of SEQ ID NO:1 or a polypeptide sequence of SEQ ID NO:2 generally is at least 80% or 85%, usually at least about 90%, and particularly at least about 95%, and preferably at least about 99% identical to the nucleotide sequence or amino acid sequence as set forth in SEQ ID NO:1 or SEQ ID NO:2, respectively. It should be recognized, however, that a mutation in a PKD1 gene sequence can result in the expression of a truncated PKD1

polypeptide, or even a complete loss of expression of the PKD1 polypeptide. As such, while a mutant PKD1 polynucleotide is identified as being substantially identical to SEQ ID NO:1, it may not always be possible to make the same comparison with respect to the encoded polypeptides. In one aspect of the invention, a polynucleotide or polypeptide sequence that is substantially identical to SEQ ID NO:1 or 2 will vary at one or more sites having a mutation, for example, a mutation present in a mutant PKD1 polynucleotide as set forth in the preceding paragraph. Sequence identity can be measured using sequence analysis software (*e.g.*, Sequence Analysis Software Package of the Genetics Computer Group, University of Wisconsin Biotechnology Center, 1710 University Avenue, Madison WI 53705).

[0058] A polynucleotide or oligonucleotide portion thereof of the invention can be useful, for example, as a probe or as a primer for an amplification reaction. Reference to an "oligonucleotide portion" of a mutant PKD1 polynucleotide means a nucleotide sequence of the mutant PKD1 polynucleotide that is less than the full length polynucleotide. Generally, a polynucleotide useful as a probe or a primer contains at least about 10 nucleotides, and usually contains about 15 to 30 nucleotides or more (see, for example, Tables 1 and 2). Polynucleotides can be prepared by any suitable method, including, for example, by restriction enzyme digestion of an appropriate polynucleotide, by direct chemical synthesis using a method such as the phosphotriester method (Narang *et al.*, 1979, *Meth. Enzymol.*, 68:90-99); the phosphodiester method (Brown *et al.*, 1979, *Meth. Enzymol.*, 68:109-151); the diethylphosphoramidite method (Beaucage *et al.*, 1981, *Tetrahedron Lett.*, 22:1859-1862); the triester method (Matteucci *et al.*, 1981, *J. Am. Chem. Soc.*, 103:3185-3191), including by automated synthesis methods; or by a solid support method (see, for example, U.S. Pat. No. 4,458,066). In addition, a polynucleotide or oligonucleotide can be prepared using recombinant DNA methods as disclosed herein or otherwise known in the art.

[0059] An oligonucleotide of the invention can include a portion of a mutant PKD1 polynucleotide, including, for example, a sequence substantially identical

to that of SEQ ID NO:1, except wherein nucleotide 474 is a T; or wherein nucleotide 487 is an A; or wherein nucleotide 3110 is a C; or wherein nucleotide 8298 is a G; or wherein nucleotide 9164 is a G; or wherein nucleotide 9213 is an A; or wherein nucleotide 9326 is a T; or wherein nucleotide 9367 is a T; or wherein nucleotide 10064 is an A; or wherein nucleotide 10143 is a G; or wherein nucleotide 10234 is a C; or wherein nucleotide 10255 is a T; or wherein the oligonucleotide contains a combination of such substitutions with respect to SEQ ID NO:1. Thus, as disclosed herein, the oligonucleotide can be any length and can encompass one or more of the above mutations.

[0060] An oligonucleotide of the invention can selectively hybridize to a mutant PKD1 polynucleotide sequence as disclosed herein. As such, the oligonucleotide does not hybridize substantially, if at all, to a wild type PKD1 polynucleotide (i.e., to SEQ ID NO:1). As used herein, the term "selectively hybridize" refers to the ability of an oligonucleotide (or polynucleotide) probe to hybridize to a selected sequence, but not to a highly related nucleotide sequence. For example, a oligonucleotide of the invention selectively hybridizes to a mutant PKD1 polynucleotide, but not substantially to a corresponding sequence of SEQ ID NO:1. As such, hybridization of the oligonucleotide to SEQ ID NO:1 generally is not above background, or, if some hybridization occurs, is at least about ten-fold less than the amount of hybridization that occurs with respect to the mutant PKD1 polynucleotide.

[0061] In addition, the term "hybridize" is used herein to have its commonly understood meaning of two nucleotide sequences that can associate due to shared complementarity. As disclosed herein, a primer of the invention can hybridize to PDK1 gene and may also hybridize to a PDK1 gene homolog, but generally does not substantially hybridize to a nucleotide sequence other than a PKD1 gene or PKD1 gene homolog. Desired hybridization conditions, including those that allow for selective hybridization, can be obtained by varying the stringency of the hybridization conditions, based, in part, on the length of the sequences involved, the relative G:C content, the salt concentration, and the like (see Sambrook *et al.*, *supra*,

representing all possible codon variations based on the degeneracy of the genetic code. One or more of the primers in this collection will be homologous with the end of the target sequence or a sequence flanking a target sequence. Likewise, if a conserved region shows significant levels of polymorphism in a population, mixtures of primers can be prepared that will amplify adjacent sequences.

[0064] During PCR amplification, primer pairs flanking a target sequence of interest are used to amplify the target sequence. A primer pair typically comprises a forward primer, which hybridizes to the 5' end of the target sequence, and a reverse primer, which hybridizes to the 3' end of the target sequence. Except as otherwise provided herein, primers of the present invention are exemplified by those having the sequences set forth as SEQ ID NOS:3 to 51 and 61 to 113 (see Tables 1 and 2). Forward primers are exemplified by SEQ ID NOS:3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47 and 49; and reverse primers are exemplified by SEQ ID NOS:4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, and 50. A primer pair of the invention includes at least one forward primer and at least one reverse primer that allows for generation of an amplification product, which can be a long range PKD1-specific amplification product or a nested amplification product of such an amplification product, including a forward and reverse primer as set forth in SEQ ID NOS:3 to 18 and of SEQ ID NOS:19 to 51 and 61 to 113, provided that the forward primer is 5' (or upstream) of the reverse primer with reference to a target polynucleotide sequence, and that the primers are in sufficient proximity such that an amplification product can be generated.

[0065] Nucleic acid sequences that encode a fusion protein can be produced and can be operatively linked to expression control sequences. Such fusion proteins and compositions are useful in the development of antibodies or to generate and purify peptides and polypeptides of interest. As used herein, the term "operatively linked" refers to a juxtaposition, wherein the components so described are in a relationship permitting them to function in their intended manner. For example, an expression control sequence operatively linked to a coding sequence is ligated

such that expression of the coding sequence is achieved under conditions compatible with the expression control sequences, whereas two operatively linked coding sequences can be ligated such that they are in the same reading frame and, therefore, encode a fusion protein.

[0066] As used herein, the term "expression control sequences" refers to nucleic acid sequences that regulate the expression of a nucleic acid sequence to which it is operatively linked. Expression control sequences are operatively linked to a nucleic acid sequence when the expression control sequences control and regulate the transcription and, as appropriate, translation of the nucleic acid sequence. Thus, expression control sequences can include appropriate promoters, enhancers, transcription terminators, a start codon (*i.e.*, ATG) in front of a protein-encoding gene, splicing signals for introns, maintenance of the correct reading frame of that gene to permit proper translation of the mRNA, and STOP codons. Control sequences include, at a minimum, components whose presence can influence expression, and can also include additional components whose presence is advantageous, for example, leader sequences and fusion partner sequences. Expression control sequences can include a promoter.

[0067] A polynucleotide of the invention can comprise a portion of a recombinant nucleic acid molecule, which, for example, can encode a fusion protein. The polynucleotide, or recombinant nucleic acid molecule, can be inserted into a vector, which can be an expression vector, and can be derived from a plasmid, a virus or the like. The expression vector generally contains an origin of replication, a promoter, and one or more genes that allow phenotypic selection of transformed cells containing the vector. Vectors suitable for use in the present invention include, but are not limited to the T7-based expression vector for expression in bacteria (Rosenberg *et al.*, Gene 56:125, 1987), the pMSXND expression vector for expression in mammalian cells (Lee and Nathans, J. Biol. Chem. 263:3521, 1988); baculovirus-derived vectors for expression in insect cells; and the like.

[0068] The choice of a vector will also depend on the size of the polynucleotide sequence and the host cell to be employed in the methods of the invention. Thus, the vector used in the invention can be plasmids, phages, cosmids, phagemids, viruses (*e.g.*, retroviruses, parainfluenzavirus, herpesviruses, reoviruses, paramyxoviruses, and the like), or selected portions thereof (*e.g.*, coat protein, spike glycoprotein, capsid protein). For example, cosmids and phagemids are typically used where the specific nucleic acid sequence to be analyzed or modified is large because these vectors are able to stably propagate large polynucleotides. Cosmids and phagemids are particularly suited for the expression or manipulation of the PKD1 polynucleotide of SEQ ID NO:1 or a mutant PKD1 polynucleotide.

[0069] In yeast, a number of vectors containing constitutive or inducible promoters can be used (see Ausubel *et al.*, *supra*, 1989; Grant *et al.*, *Meth. Enzymol.* 153:516-544, 1987; Glover, *DNA Cloning*, Vol. II, IRL Press, Washington D.C., Ch. 3, 1986; and Bitter, *Meth. Enzymol.* 152:673-684, 1987; and *The Molecular Biology of the Yeast Saccharomyces*, Eds. Strathern *et al.*, Cold Spring Harbor Press, Vols. I and II, 1982). A constitutive yeast promoter such as ADH or LEU2 or an inducible promoter such as GAL can be used ("Cloning in Yeast," Ch. 3, Rothstein, In "DNA Cloning" Vol. 11, A Practical Approach, ed. Glover, IRL Press, 1986). Alternatively, vectors can be used which promote integration of foreign DNA sequences into the yeast chromosome. The construction of expression vectors and the expression of genes in transfected cells involves the use of molecular cloning techniques also well known in the art (see Sambrook *et al.*, *supra*, 1989; Ausubel *et al.*, *supra*, 1989). These methods include *in vitro* recombinant DNA techniques, synthetic techniques and *in vivo* recombination/genetic recombination.

[0070] A polynucleotide or oligonucleotide can be contained in a vector and can be introduced into a cell by transformation or transfection of the cell. By "transformation" or "transfection" is meant a permanent (stable) or transient genetic change induced in a cell following incorporation of new DNA (*i.e.*, DNA exogenous to the cell). Where the cell is a mammalian cell, a permanent genetic

change is generally achieved by introduction of the DNA into the genome of the cell.

[0071] A transformed cell or host cell can be any prokaryotic or eukaryotic cell into which (or into an ancestor of which) has been introduced, by means of recombinant DNA techniques, a polynucleotide sequence of the invention or fragment thereof. Transformation of a host cell can be carried out by conventional techniques as are well known to those skilled in the art. Where the host is prokaryotic, such as *E. coli*, competent cells which are capable of DNA uptake can be prepared from cells harvested after exponential growth phase and subsequently treated by the CaCl₂ method by procedures well known in the art, or using MgCl₂ or RbCl. Transformation can also be performed after forming a protoplast of the host cell or by electroporation.

[0072] When the host is a eukaryote, such methods of transfection include the use of calcium phosphate co-precipitates, conventional mechanical procedures such as microinjection, electroporation, insertion of a plasmid encased in liposomes, or the use of virus vectors, or other methods known in the art. One method uses a eukaryotic viral vector, such as simian virus 40 (SV40) or bovine papillomavirus, to transiently infect or transform eukaryotic cells and express the protein. (Eukaryotic Viral Vectors, Cold Spring Harbor Laboratory, Gluzman ed., 1982). Preferably, a eukaryotic host is utilized as the host cell as described herein. The eukaryotic cell can be a yeast cell (*e.g.*, *Saccharomyces cerevisiae*), or can be a mammalian cell, including a human cell.

[0073] A variety of host-expression vector systems can be utilized to express a PKD1 polynucleotide sequence such as SEQ ID NO:1, a coding sequence of SEQ ID NO:1 or a mutant PKD1 polynucleotide. Such host-expression systems represent vehicles by which the nucleotide sequences of interest can be produced and subsequently purified, and also represent cells that, when transformed or transfected with the appropriate nucleotide coding sequences, can express a PKD1 protein, including a PKD1 variant or mutant polypeptide or peptide portion thereof *in situ*.

Such cells include, but are not limited to, microorganisms such as bacteria (*e.g.*, *E. coli*, *B. subtilis*) transformed with recombinant bacteriophage DNA, plasmid DNA or cosmid DNA expression vectors containing a PKD1 polynucleotide, or oligonucleotide portion thereof (wild type, variant or other mutant); yeast (*e.g.*, *Saccharomyces*, *Pichia*) transformed with recombinant yeast expression vectors containing a PKD1 polynucleotide, or oligonucleotide portions thereof (wild type, variant or other PKD1 mutant); insect cell systems infected with recombinant virus expression vectors (*e.g.*, baculovirus) containing a PKD1 polynucleotide, or oligonucleotide portion thereof (wild type, PKD1 variant or other mutant); plant cell systems infected with recombinant virus expression vectors (*e.g.*, cauliflower mosaic virus or tobacco mosaic virus) or transformed with recombinant plasmid expression vectors (*e.g.*, Ti plasmid) containing a mutant PKD1 polynucleotide, or oligonucleotide portion thereof; or mammalian cell systems (*e.g.*, COS, CHO, BHK, 293, 3T3) harboring recombinant expression constructs containing promoters derived from the genome of mammalian cells (*e.g.*, metallothionein promoter) or from mammalian viruses (*e.g.*, the adenovirus late promoter; the vaccinia virus 7.5K promoter).

[0074] In bacterial systems, a number of expression vectors can be advantageously selected depending upon the use intended for the PKD1 protein (wild type, variant or other PKD1 mutant) being expressed. For example, when a large quantity of such a protein is to be produced, for the generation of antibodies, which can be used to identify or diagnose PKD1-associated diseases or disorders, or to screen peptide libraries, vectors that direct the expression of high levels of fusion protein products that are readily purified can be desirable. Such vectors include, but are not limited to, the *E. coli* expression vector pUR278 (Ruther *et al.*, 1983, EMBO J. 2:1791), in which a PKD1 polynucleotide, or oligonucleotide portion thereof (wild type, variant or other mutant) can be ligated individually into the vector in frame with the lac Z coding region so that a fusion protein is produced; pIN vectors (Inouye and Inouye, Nucl. Acids Res. 13:3101-3109, 1985; Van Heeke and Schuster, J. Biol. Chem. 264:5503-5509, 1989); and the like. pGEX vectors can also be used to express foreign polypeptides as fusion proteins with glutathione S-transferase (GST). In

general, such fusion proteins are soluble and can easily be purified from lysed cells by adsorption to glutathione-agarose beads followed by elution in the presence of free glutathione. The pGEX vectors are designed to include thrombin or factor Xa protease cleavage sites so that the cloned PKD1 protein, variant or mutant can be released from the GST moiety.

[0075] In an insect system, *Autographa californica* nuclear polyhedrosis virus (AcNPV) is used as a vector to express foreign genes. The virus grows in *Spodoptera frugiperda* cells. A PKD1 polynucleotide, or oligonucleotide portion thereof can be cloned individually into non-essential regions (for example the polyhedrin gene) of the virus and placed under control of an AcNPV promoter (for example the polyhedrin promoter). Successful insertion of a PKD1 polynucleotide, or oligonucleotide portion thereof will result in inactivation of the polyhedrin gene and production of non-occluded recombinant virus (*i.e.*, virus lacking the proteinaceous coat coded for by the polyhedrin gene). These recombinant viruses are then used to infect *Spodoptera frugiperda* cells in which the inserted gene is expressed (see Smith *et al.*, 1983, J. Virol. 46:584; U.S. Pat. No. 4,215,051).

[0076] In mammalian host cells, a number of viral-based expression systems can be utilized. In cases where an adenovirus is used as an expression vector, a PKD1 polynucleotide, or oligonucleotide portion thereof, can be ligated to an adenovirus transcription/translation control complex, *e.g.*, the late promoter and tripartite leader sequence. This chimeric gene can then be inserted in the adenovirus genome by *in vitro* or *in vivo* recombination. Insertion in a non-essential region of the viral genome such as the E1 or E3 region results in a recombinant virus that is viable and capable of expressing a PKD1 protein (*e.g.*, wild-type, variants or mutants thereof) in infected hosts (Logan and Shenk, Proc. Natl. Acad. Sci., USA 81:3655-3659, 1984). Specific initiation signals can also be required for efficient translation of an inserted PKD1 sequence. These signals include the ATG initiation codon and adjacent sequences. Where an entire PKD1 polynucleotide, including its own initiation codon and adjacent sequences, is inserted into the appropriate expression vector, no additional translational control signals can be needed. However, where only a

portion of a PKD1 sequence is inserted, exogenous translational control signals, including, for example, an ATG initiation codon, must be provided. Furthermore, the initiation codon must be in phase with the reading frame of the desired coding sequence to ensure translation of the entire insert. These exogenous translational control signals and initiation codons can be of a variety of origins, both natural and synthetic. The efficiency of expression can be enhanced by the inclusion of appropriate transcription enhancer elements, transcription terminators, and the like (see Bittner *et al.*, Meth. Enzymol. 153:516-544, 1987).

[0077] In addition, a host cell strain can be chosen which modulates the expression of the inserted sequences, or modifies and processes the expressed polypeptide in a specific fashion. Such modifications (*e.g.*, glycosylation) and processing (*e.g.*, cleavage) of protein products can be important for the function of the protein. Different host cells have characteristic and specific mechanisms for the post-translational processing and modification of proteins. Appropriate cell lines or host systems can be chosen to ensure the correct modification and processing of the foreign protein being expressed. To this end, eukaryotic host cells which possess the cellular machinery for proper processing of the primary transcript, glycosylation, and phosphorylation of the polypeptide can be used. Such mammalian host cells include, but are not limited to, CHO, VERO, BHK, HeLa, COS, MDCK, 293, 3T3, WI38, and the like.

[0078] For long term, high yield production of recombinant proteins, stable expression is preferred. For example, cell lines that stably express a PKD1 protein, including wild-type, variants or mutants of PKD1, can be engineered. Rather than using expression vectors which contain viral origins of replication, host cells can be transformed with DNA controlled by appropriate expression control elements (*e.g.*, promoter and/or enhancer sequences, transcription terminators, polyadenylation sites, and the like), and a selectable marker. Following the introduction of the foreign DNA, engineered cells can be grown for 1-2 days in an enriched media, then switched to selective media. The selectable marker in the recombinant plasmid confers resistance to the selection and allows cells to stably integrate the plasmid into

their chromosomes and grow to form foci, which can be cloned and expanded into cell lines. This method can advantageously be used to engineer cell lines that express a PKD1 variant or mutant polypeptide. Such engineered cell lines can be particularly useful in screening and evaluation of compounds that affect the endogenous activity of a variant or mutant PKD1 polypeptide. Such engineered cell lines also can be useful to discriminate between factors that have specific vs. non-specific effects. In particular, mutant cell lines should lack key functions, and various mutations can be used to identify key functional domains using *in vivo* assays.

[0079] A number of selection systems can be used, including but not limited to the herpes simplex virus thymidine kinase (Wigler *et al.*, Cell 11:223, 1977), hypoxanthine-guanine phosphoribosyltransferase (Szybalska and Szybalski, Proc. Natl. Acad. Sci. USA 48:2026, 1962), and adenine phosphoribosyltransferase (Lowy *et al.*, Cell 22:817, 1980) genes can be employed in *tk*⁻, *hgp*^r or *ap*^r cells, respectively. Also, antimetabolite resistance can be used as the basis of selection for *dhfr*, which confers resistance to methotrexate (Wigler *et al.*, Proc. Natl. Acad. Sci. USA 77:3567, 1980; O'Hare *et al.*, Proc. Natl. Acad. Sci. USA 78:1527, 1981); *gpt*, which confers resistance to mycophenolic acid Mulligan and Berg, Proc. Natl. Acad. Sci. USA 78:2072, 1981); *neo*, which confers resistance to the aminoglycoside G-418 (Colberre-Garapin *et al.*, J. Mol. Biol. 150:1, 1981); and *hygro*, which confers resistance to hygromycin (Santerre *et al.*, Gene 30:147, 1984) genes. Accordingly, the invention provides a vector that contains a mutant PKD1 polynucleotide, or oligonucleotide portion thereof, or one or more primers or their complements, including an expression vector that contains any of the foregoing sequences operatively associated with a regulatory element that directs the expression of a coding sequence or primer; and also provides a host cell that contains any of the foregoing sequences, alone or operatively associated with a regulatory element, which can directs expression of a polypeptide encoded the polynucleotide, as appropriate.

[0080] In addition to mutant PKD1 polynucleotide sequences disclosed herein, homologs of mutant PKD1 polynucleotide of the invention, including a non-human species, can be identified and isolated by molecular biological techniques well known in the art. Further, mutant PKD1 alleles and additional normal alleles of the human PKD1 polynucleotide, can be identified using the methods of the invention. Still further, there can exist genes at other genetic loci within the human genome that encode proteins having extensive homology to one or more domains of the PKD1 polypeptide (SEQ ID NO:2). Such genes can also be identified including associated variants and mutants by the methods of the invention.

[0081] A homolog of a mutant PKD1 polynucleotide sequence can be isolated by performing a polymerase chain reaction (PCR; see U.S. Pat. No. 4,683,202, which is incorporated herein by reference) using two oligonucleotide primers, which can be selected, for example, from among SEQ ID NOS:3 to 51, preferably from among SEQ ID NOS: 3 to 18, or can be degenerate primer pools designed on the basis of the amino acid sequences of a PKD1 polypeptide such as that set forth in SEQ ID NO:2 or a mutant thereof as disclosed herein. The template for the reaction can be cDNA obtained by reverse transcription of mRNA prepared from human or non-human cell lines or tissue known to express a PKD1 allele or PKD1 homologue. The PCR product can be subcloned and sequenced or manipulated in any number of ways (*e.g.*, further manipulated by nested PCR) to insure that the amplified sequences represent the sequences of a PKD1 or a PKD mutant polynucleotide sequence. The PCR fragment can then be used to isolate a full length PKD1 cDNA clone (including clones containing a mutant PKD1 polynucleotide sequence) by labeling the amplified fragment and screening a nucleic acid library (*e.g.*, a bacteriophage cDNA library). Alternatively, the labeled fragment can be used to screen a genomic library (for review of cloning strategies, see, for example, Sambrook *et al.*, *supra*, 1989; Ausubel *et al.*, *supra*, 1989).

[0083] A mutant PKD1 polypeptide or peptide portion thereof can contain one or more of the exemplified mutations. As used herein, reference to a peptide portion of SEQ ID NO:2 or of a mutant PKD1 polypeptide refers to a contiguous amino acid sequence of SEQ ID NO:2 or of SEQ ID NO:2 including a mutation as disclosed herein, respectively, that contains fewer amino acids than full length wild type PKD1 polypeptide. Generally, a peptide portion of a PKD1 polypeptide or a mutant PKD1 polypeptide contains at least about five amino acids (or amino acid derivatives or modified amino acids), each linked by a peptide bond or a modified form thereof, usually contains at least about eight amino acids, particularly contains about ten amino acids, and can contain twenty or thirty or more amino acids of SEQ ID NO:2. In particular, where the peptide is a peptide portion of a mutant PKD1 polypeptide, the peptide includes a mutant amino acid with respect to SEQ ID NO:2.

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H3311R, or a mutation resulting in termination of the mutant PKD1 polypeptide at amino acid 3000 (with respect to SEQ ID NO:2) due to the presence of a STOP codon at the position that otherwise would encode amino acid 3001. The wild type PKD1 polypeptide (SEQ ID NO:2) contains 4303 amino acid residues and has a predicted molecular mass of approximately 467 kilodaltons (kDa). Further encompassed by the present invention are mutant PKD1 polypeptides that are truncated with respect to SEQ ID NO:2, for example, a mutation of SEQ ID NO:1 resulting in a G9213A, which results in premature termination of the encoded PKD1 polypeptide (see Example 2). Such truncated products can be associated with PKD1-associated disorders such as ADPKD (see, also, Table 4).

[0085] PKD1 polypeptides that are functionally equivalent to a wild type PKD1 polypeptide, including variant PKD1 polypeptides, which can contain a deletion, insertion or substitution of one or more amino acid residues with respect to SEQ ID NO:2, but that nevertheless result in a phenotype that is indistinguishable from that conferred by SEQ ID NO:2, are encompassed within the present invention. Such amino acid substitutions, for example, generally result in similarity in polarity, charge, solubility, hydrophobicity, hydrophilicity, amphipatic nature or the like of the residues involved. For example, negatively charged amino acids include aspartic acid and glutamic acid; positively charged amino acids include lysine and arginine; amino acids with uncharged polar head groups having similar hydrophilicity values include the following: leucine, isoleucine, valine, glycine, alanine, asparagine, glutamine, serine, threonine, phenylalanine and tyrosine. In many cases, however, a nucleotide substitution can be silent, resulting in no change in the encoded PKD1 polypeptide (see Example 2). Such variant PKD1 polynucleotides are exemplified by those encoded by the variant PKD1 polynucleotide sequences substantially identical to SEQ ID NO:1 (SEQ ID NO:2), but containing (encoding) G487A (A92A), C9367T (G3052G), T10234C (L3341L), and G10255T (R3348R) as shown in Table 3 (see, also, Example 2), and by C9494T (L3095L).

[0086] Mutant PKD1 polypeptides and peptide portions thereof that are substantially identical to the PKD1 polypeptide SEQ ID NO:2 or peptide portions

[0087] A PKD1 wild type or mutant polypeptide, or peptide portions thereof, can be purified from natural sources, as discussed below; can be chemically synthesized; or can be recombinantly expressed. For example, one skilled in the art can synthesize peptide fragments corresponding to a mutated portion of the PKD1 polypeptide as set forth in SEQ ID NO:2 (e.g., including residue 3110) and use the synthesized peptide fragment to generate polyclonal and monoclonal antibodies. Synthetic polypeptides or peptides can be prepared by chemical synthesis, for example, solid-phase chemical peptide synthesis methods, which are well known (see, for example, Merrifield, J. Am. Chem. Soc., 85:2149-2154, 1963; Stewart and Young, Solid Phase Peptide Synthesis, 2d ed., Pierce Chemical Co., Rockford IL, pages 11-12), and have been employed in commercially available laboratory peptide design and synthesis kits (Cambridge Research Biochemicals). Such commercially available laboratory kits have generally utilized the teachings of Geysen *et al.*, Proc. Natl. Acad. Sci., USA, 81:3998 (1984) and provide for synthesizing peptides upon the tips of a multitude of rods or pins, each of which is connected to a single plate. When such a system is utilized, a plate of rods or pins is inverted and inserted into a second plate of corresponding wells or reservoirs, which contain solutions for attaching or anchoring an appropriate amino acid to the tips of the pins or rods. By repeating such a process step, *i.e.*, inverting and inserting the tips of the rods or pins into appropriate solutions, amino acids are built into desired peptides.

[0088] A number of available Fmoc peptide synthesis systems are available. For example, assembly of a polypeptide or fragment can be carried out on a solid support using an Applied Biosystems, Inc., Model 431A automated peptide synthesizer. Such equipment provides ready access to the peptides of the invention, either by direct synthesis or by synthesis of a series of fragments that can be coupled using other known techniques. Accordingly, methods for the chemical synthesis of polypeptides and peptides are well-known to those of ordinary skill in the art, *e.g.*, peptides can be synthesized by solid phase techniques, cleaved from the resin and purified by preparative high performance liquid chromatography (see, *e.g.*, Creighton, 1983, *Proteins: Structures and Molecular Principles*, W. H. Freeman & Co., N.Y., pp. 50-60). The composition of the synthetic peptides can be confirmed by amino acid analysis or sequencing; *e.g.*, using the Edman degradation procedure (see *e.g.*, Creighton, 1983, *supra* at pp. 34-49). Thus, fragments of the PKD1 polypeptide, variant, or mutant can be chemically synthesized. Peptides can then be used, for example, to generate antibodies useful in the detection of PKD1 variants and mutants, as well as the diagnosis of PKD1-associated disorder (*e.g.*, ADPKD).

[0089] A PKD1 polypeptide or peptide, including variants or mutants of the invention, can be substantially purified from natural sources (*e.g.*, purified from cells) using protein separation techniques, well known in the art. Such methods can separate the PKD1 polypeptide away from at least about 90% (on a weight basis), and from at least about 99% of other proteins, glycoproteins, and other macromolecules normally found in such natural sources. Such purification techniques can include, but are not limited to ammonium sulfate precipitation, molecular sieve chromatography, and/or ion exchange chromatography. Alternatively, or additionally, the PKD1 polypeptide, variant, or mutant can be purified by immunoaffinity chromatography using an immunoabsorbent column to which an antibody is immobilized that is capable of specifically binding the PKD1 polypeptide, variant, or mutant. Such an antibody can be monoclonal or polyclonal in origin. For example, an antibody that specifically binds to a mutant PKD1 polypeptide does not bind to a wild-type PKD1 polypeptide or peptide thereof. If the

PKD1 polypeptide is glycosylated, the glycosylation pattern can be utilized as part of a purification scheme via, for example, lectin chromatography.

[0090] The cellular sources from which the PKD1 polypeptide, variant, or mutants thereof can be purified include, for example, those cells that are shown by northern and/or western blot analysis to express a PKD1 polynucleotide, variant, or mutant sequence. Preferably, such cellular sources are renal cells including, for example, renal tubular epithelial cells, as well as biliary duct cells, skeletal muscle cells, lung alveolar epithelial cell, placental cells, fibroblasts, lymphoblasts, intestinal epithelial cells, and endothelial cells. Other sources include biological fluids, fractionated cells such as organelle preparations, or tissues obtained from a subject. Examples of biological fluids of use with the invention are blood, serum, plasma, urine, mucous, and saliva. Tissue or cell samples can also be used with the invention. The samples can be obtained by many methods such as cellular aspiration, or by surgical removal of a biopsy sample.

[0091] PKD1 polypeptides, variants, or mutants of the invention can be secreted out of the cell. Such extracellular forms of the PKD1 polypeptide or mutants thereof can preferably be purified from whole tissue rather than cells, utilizing any of the techniques described above. PKD1 expressing cells such as those described above also can be grown in cell culture, under conditions well known to those of skill in the art. PKD1 polypeptide or mutants thereof can then be purified from the cell media using any of the techniques discussed above.

[0092] A PKD1 polypeptide, variant, or mutant can additionally be produced by recombinant DNA technology using the PKD1 nucleotide sequences, variants and mutants described above coupled with techniques well known in the art.

Alternatively, RNA capable of encoding PKD1 polypeptides, or peptide fragments thereof, can be chemically synthesized using, for example, automated or semi-automated synthesizers (see, for example, "Oligonucleotide Synthesis", 1984, Gait, ed., IRL Press, Oxford, which is incorporated herein by reference).

[0093] When used as a component in the assay systems described herein, the mutant PKD1 polypeptide or peptide can be labeled, either directly or indirectly, to facilitate detection of a complex formed between the PKD1 polypeptide and an antibody or nucleic acid sequence, for example. Any of a variety of suitable labeling systems can be used including, but not limited to, radioisotopes such as ^{125}I , enzyme labeling systems such as biotin-avidin or horseradish peroxidase, which generates a detectable colorimetric signal or light when exposed to substrate, and fluorescent labels.

[0094] The present invention also provides antibodies that specifically bind a PKD1 mutant or PKD1 variant, except that, if desired, an antibody of the invention can exclude an antibody as described in U.S. Pat. No. 5,891,628, which is incorporated herein by reference, or an antibody that that specifically binds a PKD1 mutant as described in U.S. Pat. No. 5,891,628. Antibodies that specifically bind a mutant PKD1 polypeptide are useful as diagnostic or therapeutic reagents and, therefore, can be used, for example, in a diagnostic assay for identifying a subject having or at risk of having ADPKD, and are particularly convenient when provided as a kit.

[0095] As used herein, the term "specifically binds," when used in reference to an antibody and an antigen or epitopic portion thereof, means that the antibody and the antigen (or epitope) have a dissociation constant of at least about 1×10^{-7} , generally at least about 1×10^{-8} , usually at least about 1×10^{-9} , and particularly at least about 1×10^{-10} or less. Methods for identifying and selecting an antibody having a desired specificity are well known and routine in the art (see, for example, Harlow and Lane, "Antibodies: A Laboratory Manual" (Cold Spring Harbor Pub. 1988), which is incorporated herein by reference.

[0096] Methods for producing antibodies that can specifically bind one or more PKD1 polypeptide epitopes, particularly epitopes unique to a mutant PKD1 polypeptide, are disclosed herein or otherwise well known and routine in the art. Such antibodies can be polyclonal antibodies or monoclonal antibodies (mAbs), and

can be humanized or chimeric antibodies, single chain antibodies, anti-idiotypic antibodies, and epitope-binding fragments of any of the above, including, for example, Fab fragments, F(ab')₂ fragments or fragments produced by a Fab expression library. Such antibodies can be used, for example, in the detection of PKD1 polypeptides, or mutant PKD1 polypeptides, including variant PKD1 polypeptides, which can be in a biological sample, or can be used for the inhibition of abnormal PKD1 activity. Thus, the antibodies can be utilized as part of ADPKD treatment methods, as well as in diagnostic methods, for example, to detect the presence or amount of a PKD1 polypeptide.

[0098] Antibodies that bind to a mutant PKD1 polypeptide, or peptide portion thereof, of the invention can be prepared using an intact polypeptide or fragments containing small peptides of interest as the immunizing antigen. The polypeptide or a peptide used to immunize an animal can be derived from translated cDNA or chemical synthesis, and can be conjugated to a carrier protein, if desired. Such commonly used carriers that can be chemically coupled to the peptide include keyhole limpet hemocyanin, thyroglobulin, bovine serum albumin, tetanus toxoid and others as described above or otherwise known in the art. The coupled polypeptide or peptide is then used to immunize the animal and antiserum can be collected. If desired, polyclonal or monoclonal antibodies can be purified, for example, by binding to and elution from a matrix to which the polypeptide or a

[0099] Anti-idiotype technology can be used to produce monoclonal antibodies that mimic an epitope. For example, an anti-idiotypic monoclonal antibody made to a first monoclonal antibody will have a binding domain in the hypervariable region that is the image of the epitope bound by the first monoclonal antibody. Antibodies of the invention include polyclonal antibodies, monoclonal antibodies, and fragments of polyclonal and monoclonal antibodies that specifically bind to a mutant PKD1 polypeptide or peptide portion thereof.

[1010] Monoclonal antibodies can be isolated and purified from hybridoma cultures by a variety of well-established techniques. Such isolation techniques include affinity chromatography with Protein-A Sepharose, size-exclusion

chromatography, and ion-exchange chromatography (see Coligan *et al.*, sections 2.7.1-2.7.12 and sections 2.9.1-2.9.3; Barnes *et al.*, Purification of Immunoglobulin G (IgG), in Methods in Molecular Biology, Vol. 10, pages 79-104 (Humana Press 1992)). Methods of *in vitro* and *in vivo* multiplication of hybridoma cells expressing monoclonal antibodies is well-known to those skilled in the art. Multiplication *in vitro* can be carried out in suitable culture media such as Dulbecco's Modified Eagle Medium or RPMI 1640 medium, optionally replenished by a mammalian serum such as fetal calf serum or trace elements and growth-sustaining supplements such as normal mouse peritoneal exudate cells, spleen cells, bone marrow macrophages. Production *in vitro* provides relatively pure antibody preparations and allows scale-up to yield large amounts of the desired antibodies. Large scale hybridoma cultivation can be carried out by homogenous suspension culture in an airlift reactor, in a continuous stirrer reactor, or in immobilized or entrapped cell culture. Multiplication *in vivo* can be carried out by injecting cell clones into mammals histocompatible with the parent cells, *e.g.*, syngeneic mice, to cause growth of antibody-producing tumors. Optionally, the animals are primed with a hydrocarbon, especially oils such as pristane tetramethylpentadecane prior to injection. After one to three weeks, the desired monoclonal antibody is recovered from the body fluid of the animal.

[0102] Therapeutic applications for antibodies disclosed herein are also part of the present invention. For example, antibodies of the present invention can be derived from subhuman primate antibodies. General techniques for raising therapeutically useful antibodies in baboons can be found, for example, in Goldenberg *et al.*, International Application Publication No. WO 91/11465, 1991; Losman *et al.*, Int. J. Cancer, 46:310, 1990, which are incorporated herein by reference.

[0103] An anti-PKD1 antibody also can be derived from a "humanized" monoclonal antibody. Humanized monoclonal antibodies are produced by transferring mouse complementarity determining regions from heavy and light variable chains of the mouse immunoglobulin into a human variable domain, and then substituting human residues in the framework regions of the murine

counterparts. The use of antibody components derived from humanized monoclonal antibodies obviates potential problems associated with the immunogenicity of murine constant regions. General techniques for cloning murine immunoglobulin variable domains are described, for example, by Orlandi *et al.*, Proc. Natl. Acad. Sci. USA 86:3833, 1989, which is incorporated herein by reference. Techniques for producing humanized monoclonal antibodies are described, for example, by Jones *et al.*, Nature, 321:522, 1986; Riechmann *et al.*, Nature 332:323, 1988; Verhoeyen *et al.*, Science 239:1534, 1988; Carter *et al.*, Proc. Natl. Acad. Sci. USA, 89:4285, 1992; Sandhu, Crit. Rev. Biotech. 12:437, 1992; and Singer *et al.*, J. Immunol. 150:2844, 1993, which are incorporated herein by reference.

[0104] Antibodies of the invention also can be derived from human antibody fragments isolated from a combinatorial immunoglobulin library (see, for example, Barbas *et al.*, Methods: A Companion to Methods in Enzymology, Vol. 2, page 119, 1991; Winter *et al.*, Ann. Rev. Immunol. 12:433, 1994, which are incorporated herein by reference). Cloning and expression vectors that are useful for producing a human immunoglobulin phage library can be obtained, for example, from Stratagene (La Jolla CA).

[0105] In addition, antibodies of the present invention can be derived from a human monoclonal antibody. Such antibodies are obtained from transgenic mice that have been "engineered" to produce specific human antibodies in response to antigenic challenge. In this technique, elements of the human heavy and light chain loci are introduced into strains of mice derived from embryonic stem cell lines that contain targeted disruptions of the endogenous heavy and light chain loci. The transgenic mice can synthesize human antibodies specific for human antigens, and the mice can be used to produce human antibody-secreting hybridomas. Methods for obtaining human antibodies from transgenic mice are described by Green *et al.*, Nature Genet., 7:13 (1994); Lonberg *et al.*, Nature, 368:856 (1994); Taylor *et al.*, Int. Immunol., 6:579 (1994), each of which is incorporated herein by reference.

[0106] Antibody fragments of the invention can be prepared by proteolytic hydrolysis of an antibody or by expression in *E. coli* of DNA encoding the fragment. Antibody fragments can be obtained by pepsin or papain digestion of whole antibodies by conventional methods. For example, antibody fragments can be produced by enzymatic cleavage of antibodies with pepsin to provide a 5S fragment denoted $F(ab')_2$. This fragment can be further cleaved using a thiol reducing agent, and optionally a blocking group for the sulfhydryl groups resulting from cleavage of disulfide linkages, to produce 3.5S Fab' monovalent fragments. Alternatively, an enzymatic cleavage using pepsin produces two monovalent Fab' fragments and an Fc fragment directly. These methods are described, for example, by Goldenberg, U.S. Pat. Nos. 4,036,945 and 4,331,647, and references contained therein, each of which is incorporated herein by reference (see, also, Nisonhoff *et al.*, Arch. Biochem. Biophys., 89:230, 1960; Porter, Biochem. J. 73:119, 1959; Edelman *et al.*, Meth. Enzymol. 1:422, 1967; and Coligan *et al.*, at sections 2.8.1-2.8.10 and 2.10.1-2.10.4). Other methods of cleaving antibodies, such as separation of heavy chains to form monovalent light-heavy chain fragments, further cleavage of fragments, or other enzymatic, chemical, or genetic techniques can also be used, provided the fragments bind to the antigen that is recognized by the intact antibody.

[0107] Fv fragments comprise an association of V_H and V_L chains, for example, which can be noncovalent (see Inbar *et al.*, Proc. Natl. Acad. Sci. USA 69:2659, 1972). The variable chains also can be linked by an intermolecular disulfide bond, can be crosslinked by a chemical such as glutaraldehyde (Sandhu, *supra*, 1992), or F_v fragments comprising V_H and V_L chains can be connected by a peptide linker. These single chain antigen binding proteins (sFv) are prepared by constructing a structural gene comprising DNA sequences encoding the V_H and V_L domains connected by an oligonucleotide. The structural gene is inserted into an expression vector, which is subsequently introduced into a host cell such as *E. coli*. The recombinant host cells synthesize a single polypeptide chain with a linker peptide bridging the two V domains. Methods for producing sFvs are described, for example, by Whitlow *et al.*, Methods: A Companion to Meth. Enzymol., 2:97, 1991;

Bird *et al.*, Science 242:423, 1988; Ladner *et al.*, U.S. Patent No. 4,946,778; Pack *et al.*, BioTechnology 11:1271, 1993; and Sandhu, *supra*, 1992).

[0108] Another form of an antibody fragment is a peptide coding for a single complementarity determining region (CDR). CDR peptides ("minimal recognition units") can be obtained by constructing genes encoding the CDR of an antibody of interest. Such genes are prepared, for example, by using the polymerase chain reaction to synthesize the variable region from RNA of antibody-producing cells (see, for example, Larrick *et al.*, Methods: A Companion to Meth. Enzymol., 2:106, 1991).

[0109] A variety of methods can be employed utilizing reagents such as a mutant PKD1 polynucleotide, or oligonucleotide portion thereof and antibodies directed against a mutant PKD1 polypeptide or peptide. Specifically, such reagents can be used for the detection of the presence of PKD1 mutations, *e.g.*, molecules present in diseased tissue but absent from, or present in greatly reduced levels compared or relative to the corresponding non-diseased tissue.

[0110] The methods described herein can be performed, for example, by utilizing pre-packaged kits, which can be diagnostic kits, comprising at least one specific oligonucleotide portion of a PKD1 gene or mutant PKD1 polynucleotide, a primer pair, or an anti-PKD1 antibody reagent as disclosed herein, which can be conveniently used, for example, in a clinical setting to diagnose subjects exhibiting PKD1 abnormalities or to detect PKD1-associated disorders, including ADPKD. Any tissue in which a PKD1 polynucleotide is expressed can be utilized in a diagnostic method of the invention.

[0111] Nucleic acids from a tissue to be analyzed can be isolated using procedures that are well known in the art, or a diagnostic procedures can be performed directly on a tissue section (fixed or frozen), which can be obtained from a subject by biopsy or resection, without further purification. Oligonucleotide sequences of the invention can be used as probes or primers for such *in situ* procedures (Nuovo, 1992,

PCR *in situ* hybridization: protocols and applications, Raven Press, N.Y.). For example, oligonucleotide probes useful in the diagnostic methods of the invention include nucleotide sequences having at least 10 contiguous nucleotides and having a sequence substantially identical to a portion of SEQ ID NO:1, and including nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; nucleotide 10255, wherein nucleotide 10255 is a T, or a combination thereof. Primers useful in the present invention include those set forth in SEQ ID NOS:3 to 18 and SEQ ID NOS: 19 to 51 and 61 to 112. Such primers flank and can be used to amplify sequences containing one or more mutated nucleotides of a mutant PKD1 polynucleotide.

[0112] PKD1 polynucleotide sequences, either RNA or DNA, can be used in hybridization or amplification assays of biological samples to detect abnormalities of PKD1 expression; *e.g.*, Southern or northern blot analysis, single stranded conformational polymorphism (SSCP) analysis including *in situ* hybridization assays, or polymerase chain reaction analyses, including detecting abnormalities by a methods such as denaturing high performance liquid chromatography (DHPLC; also referred to as temperature-modulated heteroduplex chromatography) or conformation sensitive gel electrophoresis (CSGE), both of which are readily adaptable to high throughput analysis (see, for example, Kristensen et al., BioTechniques 30:318-332, 2001; Leung et al., BioTechniques 30:334-340, 2001, which are incorporated herein by reference). Such analyses can reveal quantitative abnormalities in the expression pattern of the PKD1 polynucleotide, and, if the PKD1 mutation is, for example, an extensive deletion, or the result of a chromosomal rearrangement, can reveal more qualitative aspects of the PKD1 abnormality.

[0113] Diagnostic methods for detecting a mutant PKD1 polynucleotide can involve, for example, contacting and incubating nucleic acids derived from a tissue sample being analyzed, with one or more labeled oligonucleotide probes of the invention or with a primer or primer pair of the invention, under conditions favorable for the specific annealing of these reagents to their complementary sequences within the target molecule. After incubation, non-annealed oligonucleotides are removed, and hybridization of the probe or primer, if any, to a nucleic acid from the target tissue is detected. Using such a detection scheme, the target tissue nucleic acid can be immobilized, for example, to a solid support such as a membrane, or a plastic surface such as that on a microtiter plate or polystyrene beads. In this case, after incubation, non-annealed, labeled nucleic acid reagents are easily removed. Detection of the remaining, annealed, labeled nucleic acid reagents is accomplished using standard techniques well known to those in the art.

[0114] Oligonucleotide probes or primers of the invention also can be associated with a solid matrix such as a chip in an array, thus providing a means for high throughput methods of analysis. Microfabricated arrays of large numbers of oligonucleotide probes (DNA chips) are useful for a wide variety of applications. Accordingly, methods of diagnosing or detecting a PKD1 variant or mutant can be implemented using a DNA chip for analysis of a PKD1 polynucleotide and detection of mutations therein. A methodology for large scale analysis on DNA chips is described by Hacia *et al.* (Nature Genet. 14:441-447, 1996; U.S. Pat. No. 6,027,880, which are incorporated herein by reference; see, also, Kristensen *et al.*, *supra*, 2001). As described in Hacia *et al.*, high density arrays of over 96,000 oligonucleotides, each about 20 nucleotides in length, are immobilized to a single glass or silicon chip using light directed chemical synthesis. Contingent on the number and design of the oligonucleotide probe, potentially every base in a sequence can be examined for alterations.

[0115] Polynucleotides or oligonucleotides applied to a chip can contain sequence variations, which can be used to identify mutations that are not yet known to occur in

the population, or they can only those mutations that are known to occur, including those disclosed herein (see Example 2). Examples of oligonucleotides that can be applied to the chip include oligonucleotides containing at least 10 contiguous nucleotides and having a sequence substantially identical to a portion of SEQ ID NO:1, and including nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; a position corresponding to nucleotide 3336, wherein nucleotide 3336 is deleted; nucleotide 3707, wherein nucleotide 3707 is an A; nucleotide 4168, wherein nucleotide 4168 is a T; nucleotide 4885, wherein nucleotide 4885 is an A; nucleotide 5168, wherein nucleotide 5168 is a T; nucleotide 6058, wherein nucleotide 6058 is a T; nucleotide 6078, wherein nucleotide 6078 is an A; nucleotide 6089, wherein nucleotide 6089 is a T; nucleotide 6195, wherein nucleotide 6195 is an A; nucleotide 6326, wherein nucleotide 6326 is a T; a position corresponding to nucleotides 7205 to 7211, wherein nucleotides 7205 to 7211 are deleted; nucleotide 7376, wherein nucleotide 7376 is a C; a nucleotide sequence corresponding to nucleotides 7535 to 7536, wherein a GCG nucleotide sequence is inserted between nucleotides 7535 and 7536; nucleotide 7415, wherein nucleotide 7415 is a T; nucleotide 7433, wherein nucleotide 7433 is a T; nucleotide 7696, wherein nucleotide 7696 is a T; nucleotide 7883, wherein nucleotide 7883 is a T; nucleotide 8021, wherein nucleotide 8021 is an A; a nucleotide sequence corresponding to nucleotide 8159 to 8160, wherein nucleotides 8159 to 8160 are deleted; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; nucleotide 10255, wherein nucleotide 10255 is a T; or a combination thereof.

[0116] Prior to hybridization with oligonucleotide probes on the chip, the test sample is isolated, amplified and labeled (*e.g.* fluorescent markers). The test polynucleotide sample is then hybridized to the immobilized oligonucleotides. The

intensity of sequence-based techniques of the target polynucleotide to the immobilized probe is quantitated and compared to a reference sequence. The resulting genetic information can be used in molecular diagnosis. A common utility of the DNA chip in molecular diagnosis is screening for known mutations.

[0117] In addition to DNA chip methodology, methods using machinery adapted to DNA analysis can allow for commercialization of the disclosed methods of detection of PKD1 mutations and diagnosis of ADPKD. For example, genotyping by mass spectrometry can be used, or matrix-assisted laser desorption/ionization-time-of-flight (MALDI-TOF) mass spectrometry can be used for mass genotyping of single-base pair and short tandem repeat mutant and variant sequences. For example, PCR amplification of the region of the mutation with biotin attached to one of the primers can be conducted, followed by immobilization of the amplified DNA to streptavidin beads. Hybridization of a primer adjacent to the variant or mutant site is performed, then extension with DNA polymerase past the variant or mutant site in the presence of dNTPs and ddNTPs is performed. When suitably designed according to the sequence, this results in the addition of only a few additional bases (Braun, Little, Koster, 1997). The DNA is then processed to remove unused nucleotides and salts, and the short primer plus mutant site is removed by denaturation and transferred to silicon wafers using a piezoelectric pipette. The mass of the primer+variant or mutant site is then determined by delayed extraction MALDI-TOF mass spectrometry. Single base pair and tandem repeat variations in sequence are easily determined by their mass. This final step is very rapid, requiring only 5 sec per assay, and all of these steps can be automated, providing the potential of performing up to 20,000 genotypings per day. This technology is rapid, extremely accurate, and adaptable to any variant or mutation, can identify both single base pair and short tandem repeat variants, and adding or removing variant or mutant sequences to be tested can be done in a few seconds at trivial cost.

[0118] Another diagnostic methods for the detection of mutant PKD1 polynucleotides involves amplification, for example, by PCR (see U.S. Patent No. 4,683,202), ligase chain reaction (Barany, Proc. Natl. Acad. Sci. USA 88:189-

193, 1991a), self sustained sequence replication (Guatelli *et al.*, Proc. Natl. Acad. Sci. USA 87:1874-1878, 1990), transcriptional amplification system (Kwoh *et al.*, Proc. Natl. Acad. Sci. USA 86:1173-1177, 1989), Q-Beta Replicase (Lizardi *et al.*, Bio/Technology 6:1197, 1988), or any other RNA amplification method, followed by the detection of the amplification products. The present invention provides reagents, methods and compositions that can be used to overcome prior difficulties with diagnosing ADPKD.

[0119] Using the primer pairs and methods described herein, the entire replicated segment of the PKD1 gene, including exons 1 and 22, can be amplified from genomic DNA to generate a set of eight long range amplification products, which range in size from about 0.3 kb to 5.8 kb (Table 1; see, also, Figure 1). The availability of widely scattered PKD1-specific primers provides a means to anchor PKD1-specific amplification, and the ability to use various primer combinations provides a means to produce longer or shorter amplification products as desired. For example, the largest PKD1 fragment, which is amplified by primers BPF13 and KG8R25 (see Table 1; SEQ ID NOS: 17 and 18, respectively), can be divided into two shorter segments by using the PKD1-specific primer, KG85R25 (SEQ ID NO:18), with forward nested primer F32 (5'-GCCTTGCGCAGCTTGGA-3'; SEQ ID NO:53), and using BPF13 (SEQ ID NO:17) and a second specific primer, 31R (5'-ACAGTGTCTTGAGTCCAAGC-3'; SEQ ID NO:54).

[0120] It should be recognized that, while many of the primers disclosed herein are positioned with intronic sequences of the PKD1 gene, others such as SEQ ID NO:16 are positioned in coding sequences. As such, a cDNA molecule can be obtained from a target RNA molecule, for example, by reverse transcription of the RNA molecule using a primer such as SEQ ID NO:16 and an appropriate second primer positioned 5' or 3' to SEQ ID NO:16. In this embodiment, a PKD1 RNA can be isolated from any tissue in which wild type PKD1 is known to be expressed, including, for example, kidney tissue, nucleated peripheral blood cells, and fibroblasts. A target sequence within the cDNA is then used as the template for a nucleic acid amplification reaction, such as a PCR amplification reaction, or the like.

An amplification product can be detected, for example, using radioactively or fluorescently labeled nucleotides or the like and an appropriate detection system, or by generating a sufficient amount of the amplification product such that it can be visualized by ethidium bromide staining and gel electrophoresis.

[0121] Genomic DNA from a subject, including from a cell or tissue sample, can be used as the template for generating a long range PKD1-specific amplification product. Methods of isolating genomic DNA are well known and routine (see Sambrook et al., *supra*, 1989). Amplification of the genomic PKD1 DNA has advantages over the cDNA amplification process, including, for example, allowing for analysis of exons and introns of the PKD1 gene. As such, a target sequence of interest associated with either an intron or exon sequence of a PKD1 gene can be amplified and characterized. A target sequence of interest is any sequence or locus of a PKD1 gene that contains or is thought to contain a mutation, including those mutations that correlate to a PKD1-associated disorder or disease.

[0122] Using primers flanking the target sequence, a sufficient number of PCR cycles is performed to provide a PKD1-specific amplification product corresponding to the target sequence. If desired, additional amplification can be performed, for example, by performing a nested PCR reaction. Examples of primers useful for generating a PKD1-specific first amplification product from genomic DNA include the primer pairs having sequences as exemplified in SEQ ID NO:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; and SEQ ID NOS:17 and 18. The PKD1-specific first amplification product can be further amplified using nested primers specific for a target sequence, including the primer pairs exemplified as SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID

NOS:49 and 50; SEQ ID NOS:51 and 61; and the primer pairs formed using consecutive primers set forth in Table 2 as SEQ ID NOS:62 to 96, 113, and 97 to 112.

[0123] The amplified target sequences can be examined for changes (i.e., mutations) with respect to SEQ ID NO:1 using any of various well known methods as disclosed herein or otherwise known in the art. For example, the amplification products can simply be sequenced using routine DNA sequencing methods, particularly where only one or few amplification products are to be examined. However, DNA sequencing will be more valuable as a method of detecting mutations according to a method of the invention as sequencing technology improves and becomes more adaptable to high throughput screening assays. In addition, methods that are useful for detecting the presence of a mutation in a DNA sequence include, for example, DHPLC (Huber et al., Nucl. Acids Res. 21:1061-10666, 1993; Liu et al., Nucl. Acids Res. 26:1396-1400, 1998; Choy et al., Ann. Hum. Genet. 63:383-391, 1999; Ellis et al., Hum. Mutat. 15:556-564, 2000; which are incorporated herein by reference; see, also, Kristensen et al., *supra*, 2001); CSGE (Leung et al., *supra*, 2001); single-stranded conformation analysis (SSCA; Orita *et al.*, Proc. Natl. Acad. Sci., USA 86:2766-2770, 1989); denaturing gradient gel electrophoresis (DGGE; Sheffield *et al.*, Proc. Natl. Acad. Sci., USA 86:232-236, 1989); RNase protection assays; allele-specific oligonucleotides (ASOs; Handelin and Shuber, Current Protocols in Human Genetics, Suppl. 16 (John Wiley & Sons, Inc. 1998), 9:9.4.1-9.4.8); the use of proteins that recognize nucleotide mismatches, such as the *E. coli* mutS protein; and allele-specific PCR.

[0124] For allele-specific PCR, primers are used that hybridize at their 3' ends to a particular mutations. Examples of primers that can be used for allele specific PCR include an oligonucleotide of at least 10 nucleotide of SEQ ID NO:1 and that has at its 3' end nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A;

nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; or nucleotide 10255, wherein nucleotide 10255 is a T. If the particular mutation is not present, an amplification product is not observed. Amplification Refractory Mutation System (ARMS) can also be used (see European Patent Application Publ. No. 0332435; Newton *et al.*, Nucl. Acids. Res. 17:2503-2516, 1989).

[0125] In the SSCA, DGGE and RNase protection methods, a distinctive electrophoretic band appears. SSCA detects a band that migrates differentially because the sequence change causes a difference in single-strand, intramolecular base pairing. RNase protection involves cleavage of the mutant polynucleotide into two or more smaller fragments. DGGE detects differences in migration rates of mutant sequences compared to wild-type sequences, using a denaturing gradient gel. In an allele-specific oligonucleotide assay, an oligonucleotide is designed that detects a specific sequence, and the assay is performed by detecting the presence or absence of a hybridization signal. In the mutS assay, the protein binds only to sequences that contain a nucleotide mismatch in a heteroduplex between mutant and wild-type sequences.

[0126] Denaturing gradient gel electrophoresis is based on the melting behavior of the DNA fragments and the use of denaturing gradient gel electrophoresis as shown by Fischer and Lerman, Proc. Natl. Acad. Sci. USA 80:1579-83, 1983; Myers *et al.*; Nucl. Acids Res. 13:3111-3129, 1985; Lerman *et al.*, in Molecular Biol. of Homo Sapiens, Cold Spring Harbor Lab. (1986) pp. 285-297. DNA fragments differing by single base substitutions can be separated from each other by electrophoresis in polyacrylamide gels containing an ascending gradient of the DNA denaturants urea and formamide. Two identical DNA fragments differing by only one single base pair, will initially move through the polyacrylamide gel at a constant rate. As they migrate into a critical concentration of denaturant, specific domains within the fragments melt to produce partially denatured DNA. Melting of a domain is

accompanied by an abrupt decrease in mobility. The position in the denaturant gradient gel at which the decrease in mobility is observed corresponds to the melting temperature of that domain. Since a single base substitution within the melting domain results in a melting temperature difference, partial denaturation of the two DNA fragments will occur at different positions in the gel. DNA molecules can therefore be separated on the basis of very small differences in the melting temperature. Additional improvements to this DGGE have been made as disclosed by Borresen in US Patent No. 5,190,856. In addition, after a first DGGE analysis, an identified product can be cloned, purified and analyzed a second time by DGGE.

[0127] Denaturing high performance liquid chromatography (DHPLC; Kristensen et al., *supra*, 2001) and high throughput conformation sensitive gel electrophoresis (HTCSGD; Leung et al., *supra*, 2001) are particularly useful methods for detecting a mutant PKD1 polynucleotide sequence because the methods are readily adaptable to high throughput analysis. In addition, these methods are suitable for detecting known mutations as well as identifying previously unknown mutations. As such, these methods of detection can be adopted for use in clinical diagnostic settings. DHPLC, for example, can be used to rapidly screen a large number of samples, for example, 96 samples prepared using a 96 well microtiter plate format, to identify those showing a change in the denaturation properties. Where such a change is identified, confirmation that the PKD1 polynucleotide in the sample showing the altered denaturation property is a mutant PKD1 polynucleotide can be confirmed by DNA sequence analysis, if desired.

[0128] An oligonucleotide probe specific for a mutant PKD1 polynucleotide also can be used to detect a mutant PKD1 polynucleotide in a biological sample, including in a biological fluid, in cells or tissues obtained from a subject, or in a cellular fraction such as an organelle preparation. Cellular sources useful as samples for identifying a mutant PKD1 polynucleotide include, for example, renal cells including renal tubular epithelial cells, bile duct cells, skeletal muscle cells, lung alveolar epithelial cells, placental cells, fibroblasts and lymphocytes.

Biological fluids useful as samples for identifying a mutant PKD1 polynucleotide include, for example, whole blood or serum or plasma fractions, urine, mucous, and saliva. A biological sample such as a tissue or cell sample can be obtained by any method routinely used in a clinical setting, including, for example, by cellular aspiration, biopsy or other surgical procedure.

[0129] The oligonucleotide probe can be labeled with a compound that allows detection of binding to a mutant PKD1 polynucleotide in the sample. A detectable compound can be, for example, a radioactive label, which provides a highly sensitive means for detection, or a non-radioactive label such as a fluorescent, luminescent, chemiluminescent, or enzymatically detectable label or the like (see, for example, Matthews *et al.*, Anal. Biochem. 169:1-25, 1988).

[0130] The method of detection can be a direct or indirect method. An indirect detection process can involve, for example, the use of an oligonucleotide probe that is labeled with a hapten or ligand such as digoxigenin or biotin. Following hybridization, the target-probe duplex is detected by the formation of an antibody or streptavidin complex, which can further include an enzyme such as horseradish peroxidase, alkaline phosphatase, or the like. Such detection systems can be prepared using routine methods, or can be obtained from a commercial source. For example, the GENIUS detection system (Boehringer Mannheim) is useful for mutational analysis of DNA, and provides an indirect method using digoxigenin as a tag for the oligonucleotide probe and an anti-digoxigenin-antibody-alkaline phosphatase conjugate as the reagent for identifying the presence of tagged probe.

[0131] Direct detection methods can utilize, for example, fluorescent labeled oligonucleotides, lanthanide chelate labeled oligonucleotides or oligonucleotide-enzyme conjugates. Examples of fluorescent labels include fluorescein, rhodamine and phthalocyanine dyes. Examples of lanthanide chelates include complexes of europium (Eu^{3+}) or terbium (Tb^{3+}). Oligonucleotide-enzyme conjugates are particularly useful for detecting point mutations when using target-specific oligonucleotides, as they provide very high sensitivities of detection.

Oligonucleotide-enzyme conjugates can be prepared by a number of methods (Jablonski *et al.*, Nucl. Acids Res. 14:6115-6128, 1986; Li *et al.*, Nucl. Acids. Res. 15:5275-5287, 1987; Ghosh *et al.*, Bioconjugate Chem. 1:71-76, 1990). The detection of target nucleic acids using these conjugates can be carried out by filter hybridization methods or by bead-based sandwich hybridization (Ishii *et al.*, Bioconjugate Chem. 4:34-41, 1993).

[0132] Methods for detecting a labeled oligonucleotide probe are well known in the art and will depend on the particular label. For radioisotopes, detection is by autoradiography, scintillation counting or phosphor imaging. For hapten or biotin labels, detection is with antibody or streptavidin bound to a reporter enzyme such as horseradish peroxidase or alkaline phosphatase, which is then detected by enzymatic means. For fluorophor or lanthanide chelate labels, fluorescent signals can be measured with spectrofluorimeters, with or without time-resolved mode or using automated microtiter plate readers. For enzyme labels, detection is by color or dye deposition, for example, p-nitrophenyl phosphate or 5-bromo-4-chloro-3-indolyl phosphate/nitroblue tetrazolium for alkaline phosphatase, and 3,3'-diaminobenzidine-NiCl₂ for horseradish peroxidase, fluorescence by 4-methyl umbelliferyl phosphate for alkaline phosphatase, or chemiluminescence by the alkaline phosphatase dioxetane substrates LumiPhos 530 (Lumigen Inc., Detroit MI) or AMPPD and CSPD (Tropix, Inc.). Chemiluminescent detection can be carried out with X-ray or Polaroid film, or by using single photon counting luminometers, which also is a useful detection format for alkaline phosphatase labeled probes.

[0133] Mutational analysis can also be carried out by methods based on ligation of oligonucleotide sequences that anneal immediately adjacent to each other on a target DNA or RNA molecule (Wu and Wallace, Genomics 4:560-569, 1989; Landren *et al.*, Science 241:1077-1080, 1988; Nickerson *et al.*, Proc. Natl. Acad. Sci. USA 87:8923-8927, 1990; Barany, *supra*, 1991a). Ligase-mediated covalent attachment occurs only when the oligonucleotides are correctly base-paired. The ligase chain reaction (LCR) and the oligonucleotide ligation assay (OLA), which

utilize the thermostable Taq ligase for target amplification, are particularly useful for interrogating mutation loci. The elevated reaction temperatures permit the ligation reaction to be conducted with high stringency (Barany, PCR Methods and Applications 1:5-16, 1991b; Grossman *et al.*, Nucl. Acids. Res. 22:4527-4534, 1994, which are incorporated herein by reference).

[0134] Analysis of point mutations in DNA can also be carried out by using PCR and variations thereof. Mismatches can be detected by competitive oligonucleotide priming under hybridization conditions where binding of the perfectly matched primer is favored (Gibbs *et al.*, Nucl. Acids. Res. 17:2437-2448, 1989). In the amplification refractory mutation system technique (ARMS), primers can be designed to have perfect matches or mismatches with target sequences either internal or at the 3' residue (Newton *et al.*, *supra*, 1989). Under appropriate conditions, only the perfectly annealed oligonucleotide can function as a primer for the PCR reaction, thus providing a method of discrimination between normal and mutant sequences.

[0135] Detection of single base mutations in target nucleic acids can be conveniently accomplished by differential hybridization techniques using sequence-specific oligonucleotides (Suggs *et al.*, Proc. Natl. Acad. Sci. USA 78:6613-6617, 1981; Conner *et al.*, Proc. Natl. Acad. Sci. USA 80:278-282, 1983; Saiki *et al.*, Proc. Natl. Acad. Sci. USA 86:6230-6234, 1989). Mutations can be diagnosed on the basis of the higher thermal stability of the perfectly matched probes as compared to the mismatched probes. The hybridization reactions can be carried out in a filter-based format, in which the target nucleic acids are immobilized on nitrocellulose or nylon membranes and probed with oligonucleotide probes. Any of the known hybridization formats can be used, including Southern blots, slot blots, reverse dot blots, solution hybridization, solid support based sandwich hybridization, bead-based, silicon chip-based and microtiter well-based hybridization formats.

[0136] An alternative strategy involves detection of the mutant sequences by sandwich hybridization methods. In this strategy, the mutant and wild type target nucleic acids are separated from non-homologous DNA/RNA using a common capture oligonucleotide immobilized on a solid support and detected by specific oligonucleotide probes tagged with reporter labels. The capture oligonucleotides can be immobilized on microtiter plate wells or on beads (Gingeras *et al.*, J. Infect. Dis. 164:1066-1074, 1991; Richen *et al.*, Proc. Natl. Acad. Sci. USA 88:11241-11245, 1991).

[0137] Another method for analysis of a biological sample for specific mutations in a PKD1 polynucleotide sequence (*e.g.*, mutant PKD1 polynucleotides, or oligonucleotide portions thereof) is a multiplexed primer extension method. In this method primer is hybridized to a nucleic acid suspected of containing a mutation such that the primer is hybridized 3' to the suspected mutation. The primer is extended in the presence of a mixture of one to three deoxynucleoside triphosphates and one of three chain terminating deoxynucleoside triphosphates selected such that the wild-type extension product, the mutant DNA-derived extension product and the primer each are of different lengths. These steps can be repeated, such as by PCR or RT-PCR, and the resulting primer extended products and primer are then separated on the basis of molecular weight to thereby enable identification of mutant DNA-derived extension product.

[0138] In one aspect of the invention, the OLA is applied for quantitative mutational analysis of PKD1 polynucleotide sequences (Grossman, *et al.*, *supra*, 1994). In this embodiment of the invention, a thermostable ligase-catalyzed reaction is used to link a fluorescently labeled common probe with allele-specific probes. The latter probes are sequence-coded with non-nucleotide mobility modifiers that confer unique electrophoretic mobilities to the ligation products.

[0139] Oligonucleotides specific for wild type or mutant PKD1 sequences can be synthesized with different oligomeric nucleotide or non-nucleotide modifier

[0140] Mismatch detection or mutation analysis can also be performed using mismatch specific DNA intercalating agents. Such agents intercalate at a site having a mismatch followed by visualization on a polyacrylamide or agarose gel or by electrocatalysis. Accordingly, PKD1 polynucleotide sequences can be contacted with probes specific for a PKD1 mutation or probes that are wild type for an area having a specific mutation under conditions such that the PKD1 polynucleotide and probe hybridize. The hybridized sequences are then contacted with a mismatch intercalating agent and, for example, separated on a gel. Visualized bands on the gel correspond to a sequence having a mismatch. If the probes are wild-type probes mismatches will occur if the target PKD1 sequence contains a mismatch. If the probes are specific for a mutated sequence mismatches will be present where the target PKD1 sequence is wild type, but the

hybridized or duplex sequences will not contain mismatches where the probe sequence hybridizes to a PKD1 sequence containing the same mutation.

[0141] For quantitative analysis of PKD1 mutations using OLA, oligonucleotide probes are preferably labeled with fluorophor labels that provide spectrally distinguishable characteristics. In one embodiment, oligonucleotides are labeled with 5' oligomeric PEO tails. Synthesis of such 5' labeled oligonucleotides can be carried out, for example, using an automated synthesizer using standard phosphoramidite chemistry. Following cleavage from resin and deprotection with ammonium hydroxide, the (PEO)_n-oligonucleotides can be purified by reverse phase HPLC. Oligonucleotides with 3'-FAM or TET dyes (Perkin Elmer) and 5'-phosphates can be synthesized and purified by the procedure of Grossman *et al.*, *supra*, 1994. The 5'-PEO-labeled probes can be synthesized to have 5'-PEO-tails of differing lengths to facilitate distinguishing the ligated probe products both electrophoretically by size and by spectral characteristics of the fluorophor labels.

[0142] The oligonucleotide probes are used for identifying mutant PKD1 polynucleotides, which can be indicative of a PKD1-associated disorder such as ADPKD. Preferably, the probes are specific for one or more PKD1 nucleotide positions of SEQ ID NO:1 selected from nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; or nucleotide 10255, wherein nucleotide 10255 is a T. The oligonucleotide probes for the OLA assay are typically designed to have calculated melting temperatures of about 40°C to 50°C, generally about 48°C, by the nearest neighbor method (Breslaur *et al.*, Proc. Natl. Acad. Sci. USA 83:9373-9377, 1986) so that the ligation reaction can be performed at a temperature range of about 40°C to 60°C, typically from

about 45°C to about 55°C. The wild type and mutant, including variant, oligonucleotide probes can be synthesized with various combinations of PEO oligomeric tails and fluorescein dyes such as TET and FAM. These combinations of mobility modifiers and fluorophor labels furnish electrophoretically unique ligation products that can enable the monitoring of two or more PKD1 nucleotide sites in a single ligation reaction.

[0143] In one embodiment, a method of diagnosing a PKD1-associated disorder in a subject is performed by amplifying a portion of a PKD1 polynucleotide in a nucleic acid sample from a subject suspected of having a PKD1-associated disorder with at least a first primer pair to obtain a first amplification product, wherein said first primer pair is a primer pair of claim 3; amplifying the first amplification product with at least a second primer pair to obtain a nested amplification product, wherein the second primer pair is suitable for performing nested amplification of the first amplification product; and determining whether the nested amplification product has a mutation associated with a PKD1-associated disorder, wherein the presence of a mutation associated with a PKD1-associated disorder is indicative of a PKD1-associated disorder, thereby diagnosing a PKD1-associated disorder in the subject. The method can be performed using a first primer pair selected from SEQ ID NOS:3 and 4; SEQ ID NOS:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; SEQ ID NOS:17 and 18; and a combination thereof, and a second primer pair selected from SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS:51 and 61; SEQ ID NOS:62 and 63; SEQ ID NOS:64 and 65; SEQ ID NOS:66 and 67; SEQ ID NOS:68 and 69; SEQ ID NOS:70 and 71; SEQ ID NOS:72 and 73; SEQ ID NOS:74 and 75; SEQ ID NOS:76 and 77; SEQ ID NOS:78 and 79; SEQ ID NOS:80 and 81; SEQ ID NOS:82 and 83; SEQ ID NOS:84 and 85; SEQ ID NOS:86 and 87; SEQ ID

NOS:88 and 89; SEQ ID NOS:90 and 91; SEQ ID NOS:92 and 93; SEQ ID NOS:94 and 95; SEQ ID NOS:96 and 113; SEQ ID NOS:97 and 98; SEQ ID NOS:99 and 100; SEQ ID NOS:101 and 102; SEQ ID NOS:103 and 104; SEQ ID NOS: 105 and 106; SEQ ID NOS:107 and 108; SEQ ID NOS:109 and 110; or SEQ ID NOS:111 and 112; and a combination thereof.

[0144] In another embodiment, a method of diagnosing a PKD1-associated disorder in a subject is performed by amplifying a portion of PKD1 polynucleotide in a nucleic acid sample from a subject suspected of having a PKD1-associated disorder with a first primer pair to obtain a first amplification product; amplifying the first amplification product using a second primer pair to obtain a second amplification product; and detecting a mutation in the second amplification product, wherein the mutation comprises SEQ ID NO:1 wherein nucleotide 3110 is a C; nucleotide 3336 is deleted; nucleotide 3707 is an A; nucleotide 5168 is a T; nucleotide 6078 is an A; nucleotide 6089 is a T; nucleotide 6326 is a T; nucleotides 7205 to 7211 are deleted; nucleotide 7415 is a T; nucleotide 7433 is a T; nucleotide 7883 is a T; or nucleotides 8159 to 8160 are deleted; nucleotide 8298 is a G; nucleotide 9164 is a G; nucleotide 9213 is an A; or nucleotide 9326 is a T; nucleotide 10064 is an A; or wherein a GCG nucleotide sequence is inserted between nucleotides 7535 and 7536; or a combination thereof, thereby diagnosing a PKD1-associated disorder in the subject.

[0145] The present invention also provides a method of identifying a subject having or at risk of having a PKD1-associated disorder. Such a method can be performed, for example, by comprising contacting nucleic acid molecules in a sample from a subject with at least one primer pair of the invention under conditions suitable for amplification of a PKD1 polynucleotide by the primer pair, thereby generating a PKD1-specific amplification product; and testing an amplification product for the presence or absence of a mutation indicative of a PKD1-associated disorder, wherein the absence of the mutation identifies the subject as not having or at risk of the having a PKD1-associated disorder, and wherein the presence of the mutation identifies the subject as having or is at risk

of having a PKD1-associated disorder. The primer pair can be, for example, selected from SEQ ID NO:3 and 4; SEQ ID NO:5 and 6; SEQ ID NOS:7 and 8; SEQ ID NOS:9 and 10; SEQ ID NOS:11 and 12; SEQ ID NOS:13 and 14; SEQ ID NOS:15 and 16; or SEQ ID NOS:17 and 18. The PKD1-associated disorder can be autosomal dominant polycystic kidney disease, acquired cystic disease, or any other PKD-1 associated disorder, and the subject can be, for example, a vertebrate, particularly a human subject.

[0146] Such a method is particularly adaptable to a high throughput format, and, if desired, can include a step of contacting the PKD1-specific amplification product with at least a second primer pair, under conditions suitable for nested amplification of the PKD1-specific amplification product by a second primer pair, thereby generating a nested amplification product, then testing the nested amplification product for the presence or absence of a mutation indicative of a PKD1-associated disorder. The second primer pair can be any primer pair suitable for nested amplification of the PKD1-specific amplification product, for example, a primer pair selected from SEQ ID NOS:19 and 20; SEQ ID NOS:21 and 22; SEQ ID NOS:23 and 24; SEQ ID NOS:25 and 26; SEQ ID NOS:27 and 28; SEQ ID NOS:29 and 30; SEQ ID NOS:31 and 32; SEQ ID NOS:33 and 34; SEQ ID NOS:35 and 36; SEQ ID NOS:37 and 38; SEQ ID NOS:39 and 40; SEQ ID NOS:41 and 42; SEQ ID NOS:43 and 44; SEQ ID NOS:45 and 46; SEQ ID NOS:47 and 48; SEQ ID NOS:49 and 50; SEQ ID NOS:51 and 61; SEQ ID NOS:62 and 63; SEQ ID NOS:64 and 65; SEQ ID NOS:66 and 67; SEQ ID NOS:68 and 69; SEQ ID NOS:70 and 71; SEQ ID NOS:72 and 73; SEQ ID NOS:74 and 75; SEQ ID NOS:76 and 77; SEQ ID NOS:78 and 79; SEQ ID NOS:80 and 81; SEQ ID NOS:82 and 83; SEQ ID NOS:84 and 85; SEQ ID NOS:86 and 87; SEQ ID NOS:88 and 89; SEQ ID NOS:90 and 91; SEQ ID NOS:92 and 93; SEQ ID NOS:94 and 95; SEQ ID NOS:96 and 113; SEQ ID NOS:97 and 98; SEQ ID NOS:99 and 100; SEQ ID NOS:101 and 102; SEQ ID NOS:103 and 104; SEQ ID NOS: 105 and 106; SEQ ID NOS:107 and 108; SEQ ID NOS:109 and 110; or SEQ ID NOS:111 and 112; and a combination thereof.

[0147] Testing an amplification product for the presence or absence of the mutation can be performed using any of various well known methods for examining a nucleic acid molecule. For example, nucleotide sequence of the amplification product can be determined, and compared with the nucleotide sequence of a corresponding nucleotide sequence of SEQ ID NO:1. The amplification product also can be tested by determining the melting temperature of the amplification product, and comparing the melting temperature to the melting temperature of a corresponding nucleotide sequence of SEQ ID NO:1. The melting temperature can be determined, for example, using denaturing high performance liquid chromatography.

[0148] Where a nested amplification is to be performed, the method can include a step directed to reducing contamination of the PKD1-specific amplification product by genomic DNA prior to contacting the PKD1-specific amplification product with the at least second set of primer pairs. For example, contamination of the PKD1-specific amplification product can be reduced by diluting the PKD1-specific amplification product.

[0149] The mutation indicative of a of PKD1 associated disorder can be, for example, a nucleotide sequence substantially identical to SEQ ID NO:1, wherein nucleotide 3110 is a C; nucleotide 8298 is a G; nucleotide 9164 is a G; nucleotide 9213 is an A; nucleotide 9326 is a T; or nucleotide 10064 is an A; or can be a nucleotide sequence substantially identical to SEQ ID NO:1, wherein nucleotide 3336 is deleted; nucleotide 3707 is an A; nucleotide 5168 is a T; nucleotide 6078 is an A; nucleotide 6089 is a T; nucleotide 6326 is a T; nucleotides 7205 to 7211 are deleted; nucleotide 7415 is a T; nucleotide 7433 is a T; nucleotide 7883 is a T; or nucleotides 8159 to 8160 are deleted; or wherein a GCG nucleotide sequence is inserted between nucleotides 7535 and 7536.

[0150] Data that is collected pursuant to a step of detecting the presence or absence of a mutation indicative of a PKD1-associated disorder in an amplification product, which can be an amplification product generated according

to a method of the invention, including, for example, a PKD1-specific amplification product or a nested amplification product, can be accumulated, and can be formatted into a form that facilitates determining, for example, whether a subject is at risk of a PKD1-associated disorder. As such, the data can be formatted into a report that indicates whether a subject is at risk of a PKD1-associate disorder. The report can be in any of various forms, including, for example, contained in a computer random access or read-only memory, or stored on a diskette, CD, DVD, magnetic tape; presented on a visual display such as a computer monitor or other cathode ray tube or liquid crystal display; or printed on paper. Furthermore, the data, which can be formatted into a report, can be transmitted to a user interested in or privy to the information. The data or report can be transmitted using any convenient medium, for example, via the internet, by facsimile or by mail, depending on the form of the data or report.

[0151] Also provided is a method of detecting the presence of a mutant PKD1 polynucleotide in a sample by contacting a sample suspected of containing a mutant PKD1 polynucleotide with an oligonucleotide of the invention under conditions that allow the oligonucleotide to selectively hybridize with a mutant PKD1 polynucleotide; and detecting selective hybridization of the oligonucleotide and a mutant PKD1 polynucleotide, thereby detecting the presence of a mutant PKD1 polynucleotide sequence in the sample. In another embodiment, a method of detecting the presence of a mutant PKD1 polypeptide in a sample is provided, for example, by contacting a sample suspected of containing a mutant PKD1 polypeptide with an antibody of the invention under conditions that allow the antibody to specifically bind a mutant PKD1 polypeptide; and detecting specific binding of the antibody and the mutant PKD1 polypeptide in the sample, thereby detecting the presence of a mutant PKD1 polypeptide in a sample. The mutant PKD1 polypeptide can have a sequence, for example, substantially as set forth in SEQ ID NO:2, and having a mutation of A88V, W967R, L2696R, R2985G, W3001X, R3039C, V3285I, H3311R, or a combination thereof (see, also, Table 4).

[0152] Antibodies that can specifically bind wild type or mutant PKD1 polypeptides, or peptide portions thereof, can also be used as ADPKD diagnostic reagents. Such reagents provide a diagnostic method that can detect the expression of abnormal PKD1 proteins or of abnormal levels of PKD1 protein expression, including the detection of mutant PKD1 polypeptides or aberrant cellular localization of a PKD1 protein. For example, differences in the size, electronegativity, or antigenicity of the mutant PKD1 protein relative to a wild type PKD1 protein can be detected.

[0153] Diagnostic methods for the detection of mutant PKD1 polypeptides or peptide portions thereof can involve, for example, immunoassays wherein epitopes of a mutant PKD1 polypeptide are detected by their interaction with an anti-PKD1 specific antibody (e.g., an anti-mutant PKD1 specific antibody). For example, an antibody that specifically binds to a mutant PKD1 polypeptide does not bind to a wild-type PKD1 polypeptide or peptide thereof. Particular epitopes of PKD1 to which antibodies can be developed include peptides that are substantially identical to SEQ ID NO:2, and having at least five amino acids, including amino acid residue 88, wherein residue 88 is a V; residue 967, wherein residue 967 is an R; residue 2696, wherein residue 2696 is an R; residue 2985, wherein residue 2985 is a G; residue 3039, wherein residue 3039 is a C; residue 3285, wherein residue 3285 is an I; or residue 3311, wherein residue 3311 is an R; or a C-terminal peptide including amino acid residue 3000, where residue 3001 is absent and the mutant PKD1 polypeptide is truncated due to the presence of a STOP codon in the encoding mutant PKD1 polynucleotide.

[0154] Antibodies, or fragments of antibodies, such as those described, above, are useful in the present invention and can be used to quantitatively or qualitatively detect the presence of wild type or mutant PKD1 polypeptides or peptide portions thereof, for example. This can be accomplished, for example, by immunofluorescence techniques employing a fluorescently labeled antibody (see below) coupled with light microscopic, flow cytometric, or fluorimetric detection.

[0155] The antibodies (or fragments thereof) useful in the present invention can, additionally, be employed histologically, as in immunofluorescence or immunoelectron microscopy, for *in situ* detection of PKD1 polypeptide, peptides, variants or mutants thereof. Detection can be accomplished by removing a histological specimen from a subject, and applying thereto a labeled antibody of the present invention. The histological sample can be taken from a tissue suspected of exhibiting ADPKD. The antibody (or fragment) is preferably applied by overlaying the labeled antibody (or fragment) onto a biological sample. Through the use of such a procedure, it is possible to determine not only the presence of PKD1 polypeptides, but also their distribution in the examined tissue. Using the present invention, those of ordinary skill will readily perceive that any of a wide variety of histological methods (such as staining procedures) can be modified in order to achieve such *in situ* detection.

[0156] Immunoassays for wild type or mutant PKD1 polypeptide or peptide portions thereof typically comprise incubating a biological sample, such as a biological fluid, a tissue extract, freshly harvested cells, or cells that have been incubated in tissue culture, in the presence of a detectably labeled antibody capable of identifying a PKD1 polypeptide, mutant PKD1 polypeptide and peptide portions thereof, and detecting the bound antibody by any of a number of techniques well-known in the art. The biological sample can be brought in contact with and immobilized onto a solid phase support or carrier such as nitrocellulose, or other solid support that is capable of immobilizing cells, cell particles or soluble proteins. The support can then be washed with suitable buffers followed by treatment with the detectably labeled mutant PKD1 specific antibody, preferably an antibody that recognizes a developed include peptides that are substantially identical to SEQ ID NO:2, and having at least five amino acids, including amino acid residue 88, wherein residue 88 is a V; residue 967, wherein residue 967 is an R; residue 2696, wherein residue 2696 is an R; residue 2985, wherein residue 2985 is a G; residue 3039, wherein residue 3039 is a C; residue 3285, wherein residue 3285 is an I; or residue 3311, wherein residue 3311 is an R; or a C-terminal peptide including amino acid residue 3000, where residue 3001 is absent and the mutant

PKD1 polypeptide is truncated due to the presence of a STOP codon in the encoding mutant PKD1 polynucleotide (see, also, Table 4). The solid phase support can then be washed with the buffer a second time to remove unbound antibody, and the amount of bound label on solid support can be detected by conventional means specific for the label.

[0157] A "solid phase support" or "carrier" can be any support capable of binding an antigen or an antibody. Well-known supports or carriers include glass, polystyrene, polypropylene, polyethylene, dextran, nylon, amylases, natural and modified celluloses, polyacrylamides, and magnetite. The nature of the carrier can be either soluble to some extent or insoluble for the purposes of the present invention. The support material can have virtually any possible structural configuration so long as the coupled molecule is capable of binding to an antigen or antibody. Thus, the support configuration can be spherical, as in a bead, or cylindrical, as in the inside surface of a test tube, or the external surface of a rod. Alternatively, the surface can be flat such as a sheet, test strip, or the like. Those skilled in the art will know many other suitable carriers for binding antibody or antigen, or will be able to ascertain the same by use of routine experimentation.

[0158] The binding activity of a given lot of an anti-mutant PKD1 antibody can be determined according to well known methods. Those skilled in the art will be able to determine operative and optimal assay conditions for each determination by employing routine experimentation. One of the ways in which the mutant PKD1-specific antibody can be detectably labeled is by linking the antibody to an enzyme and use the enzyme labeled antibody in an enzyme immunoassay (EIA; Voller, "The Enzyme Linked Immunosorbent Assay (ELISA):, Diagnostic Horizons 2:1-7, 1978; Microbiological Associates Quarterly Publication, Walkersville, Md.); Voller *et al.*, J. Clin. Pathol. 31:507-520, 1978; Butler, Meth. Enzymol. 73:482-523, 1981; Maggio (ed.), "Enzyme Immunoassay", CRC Press, Boca Raton FL, 1980; Ishikawa *et al.*, (eds.), "Enzyme Immunoassay", Kigaku Shoin, Tokyo, 1981). The enzyme that is bound to the antibody will react with an appropriate substrate, preferably a

chromogenic substrate, in such a manner as to produce a chemical moiety that can be detected, for example, by spectrophotometric, fluorimetric or by visual means.

[0159] Enzymes that can be used to detectably label the antibody include, but are not limited to, malate dehydrogenase, staphylococcal nuclease, delta-5-steroid isomerase, yeast alcohol dehydrogenase, α -glycerophosphate, dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-6-phosphate dehydrogenase, glucoamylase and acetylcholinesterase. The detection can be accomplished by colorimetric methods that employ a chromogenic substrate for the enzyme. Detection can also be accomplished by visual comparison of the extent of enzymatic reaction of a substrate in comparison with similarly prepared standards. In addition, detection can be accomplished using any of a variety of other immunoassays, including, for example, by radioactively labeling the antibodies or antibody fragments and detecting PKD1 wild type or mutant peptides using a radioimmunoassay (RIA; see, for example, Weintraub, Principles of Radioimmunoassays, Seventh Training Course on Radioligand Assay Techniques, The Endocrine Society, March, 1986, which is incorporated herein by reference). The radioactive isotope can be detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography.

[0160] The antibody also can be labeled with a fluorescent compound. When the fluorescently labeled antibody is exposed to light of the proper wave length, its presence can then be detected due to fluorescence. Among the most commonly used fluorescent labeling compounds are fluorescein isothiocyanate, rhodamine, phycoerythrin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine. The antibody can also be detectably labeled using fluorescence emitting metals such as ^{152}Eu , or others of the lanthanide series. These metals can be attached to the antibody using such metal chelating groups as diethylenetriaminepentacetic acid (DTPA) or ethylenediaminetetraacetic acid (EDTA).

[0161] The antibody also can be detectably labeled by coupling it to a chemiluminescent compound. The presence of the chemiluminescent-tagged antibody is then determined by detecting the presence of luminescence that arises during the course of a chemical reaction. Examples of particularly useful chemiluminescent labeling compounds are luminol, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester. Likewise, a bioluminescent compound can be used to label the antibody of the present invention. Bioluminescence is a type of chemiluminescence found in biological systems in, which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Important bioluminescent compounds for purposes of labeling are luciferin, luciferase and aequorin.

[0162] *In vitro* systems can be designed to identify compounds capable of binding a mutant PKD1 polynucleotide of the invention (*e.g.*, a polynucleotide having a sequence substantially identical to SEQ ID NO:1 and having a mutation such as C474T; G487A; T3110C; T8298G; A9164G; G9213A; C9326T; C9367T; G10064A; A10143G; T10234C; or G10255T). Such compounds can include, but are not limited to, peptides made of D-and/or L-configuration amino acids in, for example, the form of random peptide libraries (see, *e.g.*, Lam *et al.*, Nature 354:82-84, 1981), phosphopeptides in, for example, the form of random or partially degenerate, directed phosphopeptide libraries (see, *e.g.*, Songyang *et al.*, Cell 72:767-778, 1993), antibodies, and small or large organic or inorganic molecules. Compounds identified can be useful, for example, in modulating the activity of PKD1 proteins, variants or mutants. For example, mutant PKD1 polypeptides of the invention can be useful in elaborating the biological function of the PKD1 protein. Such mutants can be utilized in screens for identifying compounds that disrupt normal PKD1 interactions, or can in themselves disrupt such interactions.

[0163] The principle of the assays used to identify compounds that bind to a mutant PKD1 protein involves preparing a reaction mixture of the PKD1 protein, which can be a mutant, including a variant, and the test compound under conditions

Such assays can be conducted in a heterogeneous or homogeneous format.

[0164] In addition, methods suitable for detecting protein-protein interactions can be employed for identifying novel PKD1 cellular or extracellular protein interactions based upon the mutant or variant PKD1 polypeptides of the invention. For example, some traditional methods that can be employed are co-immunoprecipitation, crosslinking and copurification through gradients or chromatographic columns. Additionally, methods that result in the simultaneous identification of the genes coding for the protein interacting with a target protein can be employed. These methods include, for example, probing expression libraries with labeled target protein, using this protein in a manner similar to antibody probing of λ gt libraries. One such method for detecting protein interactions *in vivo* is the yeast two hybrid system. One version of this system has been described (Chien *et al.*, Proc. Natl. Acad. Sci. USA 88:9578-9582, 1991) and can be performed using commercially available reagents (Clontech; Palo Alto CA).

[0166] In instances whereby ADPKD symptoms are associated with a mutation within the PKD1 polynucleotide (*e.g.*, SEQ ID NO:1 having a mutation at T3110C;

T8298G; A9164G; G9213A; C9326T; G10064A or the like; see Example 2), which produces PKD1 polypeptides having aberrant activity, compounds identified that disrupt such activity can therefore inhibit the aberrant PKD1 activity and reduce or treat ADPKD1-associated symptoms or ADPKD disease, respectively (see Table 4). For example, compounds can be identified that disrupt the interaction of mutant PKD1 polypeptides with cellular or extracellular proteins, for example, the PKD2 gene product, but do not substantially effect the interactions of the normal PKD1 protein. Such compounds can be identified by comparing the effectiveness of a compound to disrupt interactions in an assay containing normal PKD1 protein to that of an assay containing mutant PKD1 polypeptide, for example, a two hybrid assay.

[0167] The basic principle of the assay systems used to identify compounds that interfere with the interaction between the PKD1 protein, preferably a mutant PKD1 protein, and its cellular or extracellular protein binding partner or partners involves preparing a reaction mixture containing the PKD1 protein and the binding partner under conditions and for a time sufficient to allow the two proteins to interact or bind, thus forming a complex. In order to test a compound for inhibitory activity, reactions are conducted in the presence or absence of the test compound, *i.e.*, the test compound can be initially included in the reaction mixture, or added at a time subsequent to the addition of PKD1 and its cellular or extracellular binding partner; controls are incubated without the test compound or with a placebo. The formation of any complexes between the PKD1 protein and the cellular or extracellular binding partner is then detected. The formation of a complex or interaction in the control reaction, but not in the reaction mixture containing the test compound indicates that the compound interferes with the interaction of the PKD1 protein and the binding partner. As noted above, complex formation or component interaction within reaction mixtures containing the test compound and normal PKD1 protein can also be compared to complex formation or component interaction within reaction mixtures containing the test compound and mutant PKD1 protein. This comparison can be important in those cases wherein it is desirable to identify compounds that disrupt interactions of mutant but not normal PKD1 proteins.

[0168] Any of the binding compounds, including but not limited to, compounds such as those identified in the foregoing assay systems can be tested for anti-ADPKD activity. ADPKD, an autosomal dominant disorder, can involve underexpression of a wild-type PKD1 allele, or expression of a PKD1 polypeptide that exhibits little or no PKD1 activity. In such an instance, even though the PKD1 polypeptide is present, the overall level of normal PKD1 polypeptide present is insufficient and leads to ADPKD symptoms. As such increase in the level of expression of the normal PKD1 polypeptide, to levels wherein ADPKD symptoms are ameliorated would be useful. Additionally, the term can refer to an increase in the level of normal PKD1 activity in the cell, to levels wherein ADPKD symptoms are ameliorated.

[0169] The identified compounds that inhibit PKD1 expression, synthesis and/or activity can be administered to a patient at therapeutically effective doses to treat polycystic kidney disease. A therapeutically effective dose refers to that amount of the compound sufficient to result in amelioration of symptoms of polycystic kidney disease. Toxicity and therapeutic efficacy of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD₅₀ (the dose lethal to 50% of the population) and the ED₅₀ (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD₅₀/ED₅₀. Compounds that exhibit large therapeutic indices are preferred. While compounds that exhibit toxic side effects can be used, care should be taken to design a delivery system that targets such compounds to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

[0170] The data obtained from the cell culture assays and animal studies can be used in formulating a range of dosage for use in humans. The dosage of such compounds lies preferably within a range of circulating concentrations that include the ED₅₀ with little or no toxicity. The dosage can vary within this range depending upon the dosage form employed and the route of administration utilized. For any

compound used in the method of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose can be formulated in animal models to achieve a circulating plasma concentration range that includes the IC₅₀ (*i.e.*, the concentration of the test compound that achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma can be measured, for example, by high performance liquid chromatography. Additional factors that can be utilized to optimize dosage can include, for example, such factors as the severity of the ADPKD symptoms as well as the age, weight and possible additional disorders that the patient can also exhibit. Those skilled in the art will be able to determine the appropriate dose based on the above factors.

[0171] Pharmaceutical compositions for use in accordance with the present invention can be formulated in conventional manner using one or more physiologically acceptable carriers or excipients. Thus, the compounds and their physiologically acceptable salts and solvates can be formulated for administration by inhalation (either through the mouth or the nose) or oral, buccal, parenteral or rectal administration.

[0172] For oral administration, the pharmaceutical compositions can take the form of, for example, tablets or capsules prepared by conventional means with pharmaceutically acceptable excipients such as binding agents (*e.g.*, pregelatinised maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose); fillers (*e.g.*, lactose, microcrystalline cellulose or calcium hydrogen phosphate); lubricants (*e.g.*, magnesium stearate, talc or silica); disintegrants (*e.g.*, potato starch or sodium starch glycollate); or wetting agents (*e.g.*, sodium lauryl sulphate). The tablets can be coated by methods well known in the art. Liquid preparations for oral administration can take the form of, for example, solutions, syrups or suspensions, or they can be presented as a dry product for constitution with water or other suitable vehicle before use. Such liquid preparations can be prepared by conventional means with pharmaceutically acceptable additives such as suspending agents (*e.g.*, sorbitol syrup, cellulose derivatives or hydrogenated edible fats); emulsifying agents (*e.g.*,

lecithin or acacia); non-aqueous vehicles (*e.g.*, almond oil, oily esters, ethyl alcohol or fractionated vegetable oils); and preservatives (*e.g.*, methyl or propyl-p-hydroxybenzoates or sorbic acid). The preparations can also contain buffer salts, flavoring, coloring and sweetening agents as appropriate.

[0173] Preparations for oral administration can be suitably formulated to give controlled release of the active compound. For buccal administration the compositions can take the form of tablets or lozenges formulated in conventional manner.

[0174] For administration by inhalation, the compounds for use according to the present invention are conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebuliser, with the use of a suitable propellant such as dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide or other suitable gas. In the case of a pressurized aerosol the dosage unit can be determined by providing a valve to deliver a metered amount. Capsules and cartridges of *e.g.*, gelatin, for use in an inhaler can be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

[0175] The compounds can be formulated for parenteral administration by injection, *e.g.*, by bolus injection or continuous infusion. Formulations for injection can be presented in unit dosage form, *e.g.*, in ampoules or in multi-dose containers, with an added preservative. The compositions can take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and can contain formulatory agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient can be in powder form for constitution with a suitable vehicle, *e.g.*, sterile pyrogen-free water, before use. The compounds can also be formulated in rectal compositions such as suppositories or retention enemas, *e.g.*, containing conventional suppository bases such as cocoa butter or other glycerides.

[0176] In addition to the formulations described previously, the compounds can also be formulated as a depot preparation. Such long acting formulations can be administered by implantation (for example subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, the compounds can be formulated with suitable polymeric or hydrophobic materials (for example as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

[0177] The compositions can, if desired, be presented in a pack or dispenser device that can contain one or more unit dosage forms containing the active ingredient. The pack can for example comprise metal or plastic foil, such as a blister pack. The pack or dispenser device can be accompanied by instructions for administration.

[0178] Alternatively, ADPKD can be caused by the production of an aberrant mutant form of the PKD1 protein, that either interferes with the normal allele product or introduces a novel function into the cell, which then leads to the mutant phenotype. For example, a mutant PKD1 protein can compete with the wild type protein for the binding of a substance required to relay a signal inside or outside of a cell.

[0179] Cell based and animal model based assays for the identification of compounds exhibiting anti-ADPKD activity are also encompassed within the present invention. Cells that contain and express mutant PKD1 polynucleotide sequences (e.g., a sequence substantially identical to the sequence as set forth in SEQ ID NO:1 and having one or more mutations of a C474T; G487A; T3110C; T8298G; A9164G; G9213A; C9326T; C9367T; G10064A; A10143G; T10234C; G10255T or the like; see Example 2), which encode a mutant PKD1 polypeptide, and thus exhibit cellular phenotypes associated with ADPKD, can be utilized to identify compounds that possess anti-ADPKD activity. Such cells can include cell lines consisting of naturally occurring or engineered cells that express mutant or express both normal and mutant PKD1 polypeptides. Such cells include, but are not limited to renal

epithelial cells, including primary and immortalized human renal tubular cells, MDCK cells, LLPCK1 cells, and human renal carcinoma cells. Methods of transforming cell with PKD1 polynucleotide sequences encoding wild-type or mutant proteins are described above.

[0180] Cells that exhibit ADPKD-like cellular phenotypes, can be exposed to a compound suspected of exhibiting anti-ADPKD activity at a sufficient concentration and for a time sufficient to elicit an anti-ADPKD1 activity in the exposed cells. After exposure, the cells are examined to determine whether one or more of the ADPKD-like cellular phenotypes has been altered to resemble a more wild type, non-ADPKD phenotype.

[0181] Among the cellular phenotypes that can be followed in the above assays are differences in the apical/basolateral distribution of membrane proteins. For example, normal (*i.e.*, non-ADPKD) renal tubular cells *in situ* and in culture under defined conditions have a characteristic pattern of apical/basolateral distribution of cell surface markers. ADPKD renal cells, by contrast, exhibit a distribution pattern that reflects a partially reversed apical/basolateral polarity relative to the normal distribution. For example, sodium-potassium ATPase generally is found on the basolateral membranes of renal epithelial cells, but also can be found on the apical surface of ADPKD epithelial cells, both in cystic epithelia *in vivo* and in ADPKD cells in culture (Wilson *et al.*, Am. J. Physiol. 260:F420-F430, 1991). Another marker that exhibits an alteration in polarity in normal versus ADPKD affected cells is the EGF receptor, which is normally located basolaterally, but in ADPKD cells is mislocated to the apical surface. Such a apical/basolateral marker distribution phenotype can be followed, for example, by standard immunohistology techniques using antibodies specific to a markers of interest.

[0182] Assays for the function of PKD1 also can include a measure of the rate of cell growth or apoptosis, since dysregulation of epithelial cell growth can be a key step in cyst formation. The cysts are fluid filled structures lined by epithelial cells that are both hyper-proliferative and hyper-apoptotic (Evan *et al.*, Kidney

[0183] Further, in studies of rodent models of polycystic kidney disease, the epithelial cells that line cysts of animals with naturally occurring forms of PKD showed abnormalities similar to those reported in human ADPKD (Harding *et al.*, 1992; Ramasubbu *et al.*, J. Am. Soc. Nephrol. 2:937-945, 1998; Rankin *et al.*, J. Cell Physiol. 152:578-586, 1992; Rankin *et al.*, *In Vitro* Cell Devel. Biol. Anim. 32:100-106, 1996, each of which is incorporated herein by reference). Moreover, mice that have transgenic over-expression of either c-myc or SV40-large T antigen developed PKD (Kelley *et al.* J. Am. Soc. Nephrol. 2:84-97, 1991; Trudel *et al.*, Kidney Int. 39:665-671 1991, each of which is incorporated herein by reference). Also, expression of recombinant full length PKD1 in epithelial cells reduced their rate of growth and induced resistance to apoptosis when challenged with stimuli such as serum starvation or exposure to UV light, which are known to stimulate apoptosis (Boletta *et al.*, Mol. Cell 6:1267-1273, 2000, which is incorporated herein by reference). As such, biochemical pathways that are activated by PKD1 expression, including, for example, JAK2, STAT1/3, PI3 kinase, p21, and AKT, can provide surrogate markers for PKD1 activity.

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expression of full length PKD1 induces spontaneous tubulogenesis in MDCK cells (Boletta *et al.*, *supra*, 2000). In this model system, control MDCK cells, which did not express recombinant wild type full length PKD1, formed cystic structures unless treated with hepatocyte growth factor or with fibroblast conditioned medium when cultured suspended in collagen. In contrast, MDCK cells that expressed the full length wild type recombinant form of PKD1 spontaneously formed tubules in the absence of exogenous factors when cultured in this manner. As such, this model system can be used to identify ligands that bind to and activate the PKD1 protein, to determine pathways that are targeted for activation by therapeutic agents, and as an assay system to evaluate the effect of sequence variants on PKD1 function.

[0185] Additionally, assays for the function of a PKD1 polypeptide can, for example, include a measure of extracellular matrix (ECM) components, such as proteoglycans, laminin, fibronectin and the like, in that studies in both ADPKD and in rat models of acquired cystic disease (Carone *et al.*, *Kidney International* 35:1034-1040, 1989) have shown alterations in such components. Thus, any compound that serves to create an extracellular matrix environment that more fully mimics the normal ECM should be considered as a candidate for testing for an ability to ameliorate ADPKD symptoms.

[0186] In addition, it is contemplated that the present invention can be used to measure the ability of a compound, such as those identified in the foregoing binding assays, to prevent or inhibit disease in animal models for ADPKD. Several naturally-occurring mutations for renal cystic disease have been found in animals, and are accepted in the art as models of ADPKD and provide test systems for assaying the effects of compounds that interact with PKD1 proteins. Of these models, the Han:SPRD rat model, provides an autosomal dominant model system (see, for example, Kaspereit-Rittinghausen *et al.*, *Vet. Path.* 26:195, 1989), and several recessive models also are available (Reeders, *Nature Genetics* 1:235, 1992). In addition, knock-out mice, in which the PKD1 or PKD2 gene has been disrupted, are available and provide a relevant model system for genetic

forms of ADPKD. As such, the PKD1 and PKD2 knock-out mice can be useful for confirming the effectiveness *in vivo* of compounds that interact with PKD1 proteins *in vitro* (see, for example, Wu *et al.*, Nat. Genet. 24:75-78, 2000; Kim *et al.*, Proc. Natl. Acad. Sci., USA 97:1731-1736, 2000; Lu *et al.*, Nat. Genet. 21:160-161, 1999; Wu *et al.*, Cell 93:177-188, 1998; Lu *et al.*, Nat. Genet. 17:179-181, 1997, each of which is incorporated herein by reference).

[0187] Animal models exhibiting ADPKD-like symptoms associated with one or more of the mutant PKD1 polynucleotide sequences as disclosed herein can also be engineered by utilizing the PKD1 polynucleotide sequences such in conjunction with well known methods for producing transgenic animals. Animals of any species, including, but not limited to, mice, rats, rabbits, guinea pigs, pigs, mini-pigs, goats, and non-human primates, *e.g.*, baboons, squirrels, monkeys, and chimpanzees can be used to generate such ADPKD animal models or transgenic animals. In instances where the PKD1 mutation leading to ADPKD symptoms causes a drop in the level of PKD1 protein or causes an ineffective PKD1 protein to be made (*e.g.*, the PKD1 mutation is a dominant loss-of-function mutation, such as a W3001X, *i.e.*, truncated after amino acid residue 3000, or a T3110C mutation; see, also, Table 4) various strategies can be utilized to generate animal models exhibiting ADPKD-like symptoms.

[0188] The present invention also provides transgenic non-human organisms, including invertebrates, vertebrates and mammals. For purposes of the subject invention, these animals are referred to as "transgenic" when such animal has had a heterologous DNA sequence, or one or more additional DNA sequences normally endogenous to the animal (collectively referred to herein as "transgenes") chromosomally integrated into the germ cells of the animal. The transgenic animal (including its progeny) will also have the transgene integrated into the chromosomes of somatic cells.

[0189] Various methods to make the transgenic animals of the subject invention can be employed. Generally speaking, three such methods can be employed. In one

such method, an embryo at the pronuclear stage (a "one cell embryo") is harvested from a female and the transgene is microinjected into the embryo, in which case the transgene will be chromosomally integrated into both the germ cells and somatic cells of the resulting mature animal. In another such method, embryonic stem cells are isolated and the transgene incorporated therein by electroporation, plasmid transfection or microinjection, followed by reintroduction of the stem cells into the embryo where they colonize and contribute to the germ line. Methods for microinjection of mammalian species is described in U.S. Pat. No. 4,873,191.

[0190] In yet another such method, embryonic cells are infected with a retrovirus containing the transgene whereby the germ cells of the embryo have the transgene chromosomally integrated therein. When the animals to be made transgenic are avian, because avian fertilized ova generally go through cell division for the first twenty hours in the oviduct, microinjection into the pronucleus of the fertilized egg is problematic due to the inaccessibility of the pronucleus. Therefore, of the methods to make transgenic animals described generally above, retrovirus infection is preferred for avian species, for example as described in U.S. Pat. No. 5,162,215. If microinjection is to be used with avian species, however, the method of Love *et al.*, (Biotechnology, 12, Jan 1994) can be utilized whereby the embryo is obtained from a sacrificed hen approximately two and one-half hours after the laying of the previous laid egg, the transgene is microinjected into the cytoplasm of the germinal disc and the embryo is cultured in a host shell until maturity. When the animals to be made transgenic are bovine or porcine, microinjection can be hampered by the opacity of the ova thereby making the nuclei difficult to identify by traditional differential interference-contrast microscopy. To overcome this problem, the ova can first be centrifuged to segregate the pronuclei for better visualization.

[0191] The non-human transgenic animals of the invention include, for example, bovine, porcine, ovine and avian animals (*e.g.*, cow, pig, sheep, chicken, turkey). Such transgenic non-human animals are produced by introducing a transgene into the germline of the non-human animal. Embryonal target cells at various developmental stages can be used to introduce transgenes. Different methods are used depending on

the stage of development of the embryonal target cell. The zygote is the best target for microinjection. The use of zygotes as a target for gene transfer has a major advantage in that in most cases the injected DNA will be incorporated into the host gene before the first cleavage (Brinster *et al.*, Proc. Natl. Acad. Sci. USA 82:4438-4442, 1985). As a consequence, all cells of the transgenic non-human animal will carry the incorporated transgene. This will in general also be reflected in the efficient transmission of the transgene to offspring of the founder since 50% of the germ cells will harbor the transgene.

[0192] The term "transgenic" is used to describe an animal that includes exogenous genetic material within all of its cells. A transgenic animal can be produced by cross-breeding two chimeric animals that include exogenous genetic material within cells used in reproduction. Twenty-five percent of the resulting offspring will be transgenic *i.e.*, animals that include the exogenous genetic material within all of their cells in both alleles. 50% of the resulting animals will include the exogenous genetic material within one allele and 25% will include no exogenous genetic material.

[0193] In the microinjection method useful in the practice of the invention, the transgene is digested and purified free from any vector DNA *e.g.* by gel electrophoresis. It is preferred that the transgene include an operatively associated promoter that interacts with cellular proteins involved in transcription, ultimately resulting in constitutive expression. Promoters useful in this regard include those from cytomegalovirus (CMV), Moloney leukemia virus (MLV), and herpes virus, as well as those from the genes encoding metallothionein, skeletal actin, P-enolpyruvate carboxylase (PEPCK), phosphoglycerate (PGK), DHFR, and thymidine kinase. Promoters for viral long terminal repeats (LTRs) such as Rous Sarcoma Virus can also be employed. When the animals to be made transgenic are avian, preferred promoters include those for the chicken β -globin gene, chicken lysozyme gene, and avian leukosis virus. Constructs useful in plasmid transfection of embryonic stem cells will employ additional regulatory elements well known in the art such as

enhancer elements to stimulate transcription, splice acceptors, termination and polyadenylation signals, and ribosome binding sites to permit translation.

[0194] Retroviral infection can also be used to introduce transgene into a non-human animal, as described above. The developing non-human embryo can be cultured *in vitro* to the blastocyst stage. During this time, the blastomeres can be targets for retro viral infection (Jaenich, Proc. Natl. Acad. Sci. USA 73:1260-1264, 1976). Efficient infection of the blastomeres is obtained by enzymatic treatment to remove the zona pellucida (Hogan *et al.*, In "Manipulating the Mouse Embryo" (Cold Spring Harbor Laboratory Press, Cold Spring Harbor NY 1986)). The viral vector system used to introduce the transgene is typically a replication-defective retro virus carrying the transgene (Jahner *et al.*, Proc. Natl. Acad. Sci. USA 82:6927-6931, 1985; Van der Putten *et al.*, Proc. Natl. Acad. Sci. USA 82:6148-6152, 1985). Transfection is easily and efficiently obtained by culturing the blastomeres on a monolayer of virus-producing cells (Van der Putten, *supra*; Stewart, *et al.*, EMBO J. 6:383-388, 1987). Alternatively, infection can be performed at a later stage. Virus or virus-producing cells can be injected into the blastocoele (Jahner *et al.*, Nature 298:623-628, 1982). Most of the founders will be mosaic for the transgene since incorporation occurs only in a subset of the cells that formed the transgenic nonhuman animal. Further, the founder can contain various retroviral insertions of the transgene at different positions in the genome that generally will segregate in the offspring. In addition, it is also possible to introduce transgenes into the germ line, albeit with low efficiency, by intrauterine retroviral infection of the midgestation embryo (Jahner *et al.*, *supra*, 1982).

[0195] A third type of target cell for transgene introduction is the embryonal stem cell (ES). ES cells are obtained from pre-implantation embryos cultured *in vitro* and fused with embryos (Evans *et al.* Nature 292:154-156, 1981; Bradley *et al.*, Nature 309:255-258, 1984; Gossler *et al.*, Proc. Natl. Acad. Sci. USA 83:9065-9069, 1986; and Robertson *et al.*, Nature 322:445-448, 1986). Transgenes can be efficiently introduced into the ES cells by DNA transfection or by retro virus-mediated transduction. Such transformed ES cells can thereafter be combined with blastocysts

from a nonhuman animal. The ES cells thereafter colonize the embryo and contribute to the germ line of the resulting chimeric animal (for review see Jaenisch, Science 240:1468-1474, 1988).

[0196] The transgene can be any piece of DNA that is inserted by artifice into a cell, and becomes part of the genome of the organism (*i.e.*, either stably integrated or as a stable extrachromosomal element) that develops from that cell. Such a transgene can include a gene that is partly or entirely heterologous (*i.e.*, foreign) to the transgenic organism, or can represent a gene homologous to an endogenous gene of the organism. Included within this definition is a transgene created by the providing of an RNA sequence that is transcribed into DNA, then incorporated into the genome. The transgenes of the invention include DNA sequences that encode a mutant PKD1 polypeptide, for example, a polypeptide having an amino acid sequence substantially identical to SEQ ID NO:2 and having a mutation of a A88V, a W967R, a L2696R, an R2985G, an R3039C, a V3285I, a H3311R, or any combination thereof; or encoding a truncated PKD1 polypeptide ending at amino acid 3000 (also referred to herein as "W3001X", where "X" indicates STOP codon; see, also, Table 4) and include sense, antisense, and dominant negative encoding polynucleotides, which can be expressed in a transgenic non-human animal. The term "transgenic" as used herein also includes any organism whose genome has been altered by *in vitro* manipulation of the early embryo or fertilized egg or by any transgenic technology to induce a specific gene knockout. The term "gene knockout" as used herein, refers to the targeted disruption of a gene *in vivo* with complete or partial loss of function that has been achieved by any transgenic technology familiar to those in the art. In one embodiment, transgenic animals having a gene knockout are those in which the target gene has been rendered nonfunctional by an insertion targeted to the gene to be rendered non-functional by homologous recombination.

[0197] The invention also includes animals having heterozygous mutations in or partial inhibition of function or expression of a PKD1 polypeptide. One of skill in the art would readily be able to determine if a particular mutation or if an antisense

molecule was able to partially inhibit PKD1 expression. For example, *in vitro* testing can be desirable initially by comparison with wild-type (*e.g.*, comparison of northern blots to examine a decrease in expression). After an embryo has been microinjected, colonized with transfected embryonic stem cells or infected with a retrovirus containing the transgene (except for practice of the subject invention in avian species, which is addressed elsewhere herein), the embryo is implanted into the oviduct of a pseudopregnant female. The progeny are tested for incorporation of the transgene by Southern blot analysis of blood samples using transgene specific probes. PCR is particularly useful in this regard. Positive progeny (P_0) are crossbred to produce offspring (P_1) that are analyzed for transgene expression by northern blot analysis of tissue samples.

[0198] In order to distinguish expression of like species transgenes from expression of an endogenous PKD1-related gene, a marker gene fragment can be included in the construct in the 3' untranslated region of the transgene and the northern blot probe designed to probe for the marker gene fragment. The serum levels of a PKD1 polypeptide can also be measured in the transgenic animal to determine the level of PKD1 expression. A method of creating a transgenic organism also can include methods of inserting a transgene into, for example, an embryo of an already created transgenic organism, the organism being transgenic for a different unrelated gene or polypeptide.

[0199] Transgenic organisms of the invention are highly useful in the production of organisms for study of, for example, polycystic kidney disease or PKD1-related diseases or disorders and in identifying agents or drugs that inhibit or modulate polycystic kidney disease, PKD1 associated disorders and inheritance. Expression of a mutant human PKD1 polynucleotide can be assayed, for example, by standard northern blot analysis, and the production of the mutant human PKD1 polypeptide can be assayed, for example, by detecting its presence using an antibody directed against the mutant human PKD1 polypeptide. Those animals found to express the mutant human PKD1 polypeptide can then be observed for the development of ADPKD-like symptoms.

[0200] As discussed above, animal models of ADPKD can be produced by engineering animals containing mutations in a copy of an endogenous PKD1 gene that correspond to mutations within the human PKD1 polynucleotide. Utilizing such a strategy, a PKD1 homologue can be identified and cloned from the animal of interest, using techniques such as those described herein. One or more mutations can be engineered into such a PKD1 homologue that correspond to mutations within the human PKD1 polynucleotide, as discussed above (*e.g.*, resulting in a mutation of the amino acid sequence as set forth in SEQ ID NO:2 and having a mutation of a A88V, a W967R, a L2696R, an R2985G, a W3001X, an R3039C, a V3285I, a H3311R, or any combination thereof; see, also, Table 4). As disclosed herein, a mutant polypeptide produced by such an engineered corresponding PKD1 homologue can exhibit an aberrant PKD1 activity that is substantially similar to that exhibited by a mutant human PKD1 protein. The engineered PKD1 homologue can then be introduced into the genome of the animal of interest, using techniques such as those described, above. Accordingly, any of the ADPKD animal models described herein can be used to test compounds for an ability to ameliorate ADPKD symptoms, including those associated with the expression of a mutant PKD1 polypeptide substantially identical to SEQ ID NO:2 and having the mutation A88V, W967R, L2696R, R2985G, W3001X, R3039C, V3285I, H3311R, or a combination thereof (see Example 2 and Table 4).

[0201] As discussed above, mutations in the PKD1 polynucleotide that cause ADPKD can produce a form of the PKD1 protein that exhibits an aberrant activity that leads to the formation of ADPKD symptoms. A variety of techniques can be utilized to inhibit the expression, synthesis, or activity of such mutant PKD1 polynucleotides and polypeptides. For example, compounds such as those identified through assays described, above, which exhibit inhibitory activity, can be used in accordance with the invention to ameliorate ADPKD symptoms. Such molecules can include, but are not limited, to small and large organic molecules, peptides, and antibodies. Further, antisense and ribozyme molecules that inhibit expression of a PKD1 polynucleotide, (*e.g.*, a mutant PKD1 polynucleotide), can also be used to

inhibit the aberrant PKD1 activity. Such techniques are described, below. In yet another embodiment, triple helix molecules can be utilized in inhibiting aberrant PKD1 activity.

[0202] Among the compounds that can exhibit anti-ADPKD activity are antisense, ribozyme, and triple helix molecules. Such molecules can be designed to reduce or inhibit mutant PKD1 activity by modulating the expression or synthesis of PKD1 polypeptides. Techniques for the production and use of such molecules are well known to those of skill in the art.

[0203] Double stranded interfering RNA molecules are especially useful to inhibit expression of a target gene. For example, double stranded RNA molecules can be injected into a target cell or organism to inhibit expression of a gene and the resultant polypeptide's activity. It has been found that such double stranded RNA molecules are more effective at inhibiting expression than either RNA strand alone (Fire *et al.*, Nature, **19**:391(6669):806-11, 1998).

[0204] When a disorder is associated with abnormal expression of a PKD1 polypeptide (*e.g.*, overexpression, or expression of a mutated form of the protein), a therapeutic approach that directly interferes with the translation of a PKD1 polypeptide (*e.g.*, a wild type, variant or mutant PKD1 polypeptide) is possible. Alternatively, similar methodology can be used to study gene activity. For example, antisense nucleic acid, double stranded interfering RNA or ribozymes could be used to bind to a PKD1 mRNA sequence or to cleave it. Antisense RNA or DNA molecules bind specifically with a targeted gene's RNA message, interrupting the expression of that gene's protein product. The antisense binds to the messenger RNA forming a double stranded molecule that cannot be translated by the cell. Antisense oligonucleotides of about 15 to 25 nucleotides are preferred since they are easily synthesized and have an inhibitory effect just like antisense RNA molecules. In addition, chemically reactive groups, such as iron-linked ethylenediaminetetraacetic acid (EDTA-Fe) can be attached to an antisense oligonucleotide, causing cleavage of the RNA at the site of hybridization. Antisense

nucleic acids are DNA or RNA molecules that are complementary to at least a portion of a specific mRNA molecule (Weintraub, Scientific American, 262:40, 1990). In the cell, the antisense nucleic acids hybridize to the corresponding mRNA, forming a double-stranded molecule. The antisense nucleic acids interfere with the translation of the mRNA, since the cell will not translate a mRNA that is double-stranded. Antisense oligomers of at least about 15 nucleotides also are preferred because they are less likely to cause problems when introduced into the target PKD1 polypeptide producing cell. The use of antisense methods to inhibit the *in vitro* translation of genes is well known in the art (Marcus-Sakura, Anal. Biochem., 172:289, 1988).

[0205] Use of an oligonucleotide to stall transcription is known as the triplex strategy since the oligomer winds around double-helical DNA, forming a three-strand helix. Therefore, these triplex compounds can be designed to recognize a unique site on a chosen gene (Maher *et al.*, Antisense Res. and Devel., 1:227, 1991; Helene, Anticancer Drug Design, 6:569, 1991).

[0206] Ribozymes are RNA molecules possessing the ability to specifically cleave other single-stranded RNA in a manner analogous to DNA restriction endonucleases. Through the modification of nucleotide sequences that encode these RNAs, it is possible to engineer molecules that recognize specific nucleotide sequences in an RNA molecule and cleave it (Cech, J. Amer. Med. Assn., 260:3030, 1988). A major advantage of this approach is that, because they are sequence-specific, only mRNAs with particular sequences are inactivated.

[0207] There are two basic types of ribozymes namely, tetrahymena-type (Hasselhoff, Nature, 334:585, 1988) and "hammerhead"-type. Tetrahymena-type ribozymes recognize sequences that are four bases in length, while "hammerhead"-type ribozymes recognize base sequences 11-18 bases in length. The longer the recognition sequence, the greater the likelihood that the sequence will occur exclusively in the target mRNA species. Consequently, hammerhead-type ribozymes are preferable to tetrahymena-type ribozymes for inactivating a specific

mRNA species and 18-base recognition sequences are preferable to shorter recognition sequences. These and other uses of antisense and ribozymes methods to inhibit the *in vivo* translation of genes are known in the art (*e.g.*, De Mesmaeker *et al.*, Curr. Opin. Struct. Biol., 5:343, 1995; Gewirtz *et al.*, Proc. Natl. Acad. Sci. USA, 93:3161, 1996b; Stein, Chem. and Biol. 3:319, 1996).

[0208] Specific ribozyme cleavage sites within any potential RNA target are initially identified by scanning the target molecule for ribozyme cleavage sites, which include the following sequence: GUA, GUU and GUC. Once identified, short RNA sequences of about 15 to 30 ribonucleotides corresponding to the region of the target gene containing the cleavage site can be evaluated for predicted structural features, such as secondary structure, that can render the oligonucleotide sequence unsuitable. The suitability of candidate targets can also be evaluated by testing their accessibility to hybridization with complementary oligonucleotides, using ribonuclease protection assays.

[0209] It is possible that the antisense, ribozyme, or triple helix molecules described herein can reduce or inhibit the translation of mRNA produced by mutant PKD1 alleles of the invention. In order to ensure that substantial normal levels of PKD1 activity are maintained in the cell, nucleic acid molecules that encode and express PKD1 polypeptides exhibiting normal PKD1 activity can be introduced into cells that do not contain sequences susceptible to whatever antisense, ribozyme, or triple helix treatments. Such sequences can be introduced via gene therapy methods such as those described, below. Alternatively, it can be preferable to coadminister normal PKD1 protein into the cell or tissue in order to maintain the requisite level of cellular or tissue PKD1 activity.

[0210] Antisense RNA and DNA molecules, ribozyme molecules and triple helix molecules of the invention can be prepared by any method known in the art for the synthesis of DNA and RNA molecules. These include techniques for chemically synthesizing oligodeoxyribonucleotides and oligoribonucleotides well known in the art such as for example solid phase phosphoramidite chemical synthesis.

Alternatively, RNA molecules can be generated by *in vitro* and *in vivo* transcription of DNA sequences encoding the antisense RNA molecule. Such DNA sequences can be incorporated into a wide variety of vectors that incorporate suitable RNA polymerase promoters such as the T7 or SP6 polymerase promoters. Alternatively, antisense cDNA constructs that synthesize antisense RNA constitutively or inducibly, depending on the promoter used, can be introduced stably into cell lines.

[0211] Various well known modifications to the DNA molecules can be introduced as a means of increasing intracellular stability and half-life. Possible modifications include, but are not limited to, the addition of flanking sequences of ribonucleotide or deoxyribonucleotides to the 5' or 3' end or both of the molecule or the use of phosphorothioate or 2'-O-methyl rather than phosphodiesterase linkages within the oligodeoxyribonucleotide backbone.

[0212] As discussed above, mutations in the PKD1 polynucleotide that cause ADPKD can lower the level of expression of the PKD1 polynucleotide or; alternatively, can cause inactive or substantially inactive PKD1 proteins to be produced. In either instance, the result is an overall lower level of normal PKD1 activity in the tissues or cells in which PKD1 is normally expressed. This lower level of PKD1 activity, then, leads to ADPKD symptoms. Thus, such PKD1 mutations represent dominant loss-of-function mutations. For example, a polynucleotide having a sequence as set forth in SEQ ID NO:1 and having a mutation of a G9213A results in early termination of PKD1.

[0213] For example, normal PKD1 protein, at a level sufficient to ameliorate ADPKD symptoms can be administered to a patient exhibiting such symptoms or having a mutant PKD1 polynucleotide. Additionally, DNA sequences encoding normal PKD1 protein can be directly administered to a patient exhibiting ADPKD symptoms or administered to prevent or reduce ADPKD symptoms where they have been diagnosed as having a PKD1 mutation identified herein but have not yet demonstrated symptoms. Such administration can be at a concentration sufficient to produce a level of PKD1 protein such that ADPKD symptoms are ameliorated.

[0214] Further, subjects with these types of mutations can be treated by gene replacement therapy. A copy of the normal PKD1 polynucleotide can be inserted into cells, renal cells, for example, using viral or non-viral vectors that include, but are not limited to vectors derived from, for example, retroviruses, vaccinia virus, adeno-associated virus, herpes viruses, bovine papilloma virus or non-viral vectors, such as plasmids. In addition, techniques frequently employed by those skilled in the art for introducing DNA into mammalian cells can be utilized. For example, methods including but not limited to electroporation, DEAE-dextran mediated DNA transfer, DNA guns, liposomes, direct injection, and the like can be utilized to transfer recombinant vectors into host cells. Alternatively, the DNA can be transferred into cells through conjugation to proteins that are normally targeted to the inside of a cell. For example, the DNA can be conjugated to viral proteins that normally target viral particles into the targeted host cell.

[0215] Administering the whole gene or polypeptide is not necessary to avoid the appearance of ADPKD symptoms. The use of a "minigene" therapy approach also can serve to ameliorate such ADPKD symptoms (see Ragot *et al.*, Nature 3:647, 1993; Dunckley *et al.*, Hum. Mol. Genet. 2:717-723, 1993). A minigene system uses a portion of the PKD1 coding region that encodes a partial, yet active or substantially active PKD1 polypeptide. As used herein, "substantially active" means that the polypeptide serves to ameliorate ADPKD symptoms. Thus, the minigene system utilizes only that portion of the normal PKD1 polynucleotide that encodes a portion of the PKD1 polypeptide capable of ameliorating ADPKD symptoms, and can, therefore represent an effective and even more efficient ADPKD therapy than full-length gene therapy approaches. Such a minigene can be inserted into cells and utilized via the procedures described, above, for full-length gene replacement. The cells into which the PKD1 minigene are to be introduced are, preferably, those cells, such as renal cells, which are affected by ADPKD. Alternatively, any suitable cell can be transfected with a PKD1 minigene so long as the minigene is expressed in a sustained, stable fashion and produces a polypeptide that ameliorates ADPKD symptoms.

[0216] A therapeutic minigene for the amelioration of ADPKD symptoms can comprise a nucleotide sequence that encodes at least one PKD1 polypeptide peptide domain, particularly a domain having an amino acid sequence substantially identical to a peptide portion SEQ ID NO:2 and having a mutation as shown in Table 4, for example, an A88V, W967R, L2696R, R2985G, W3001X, R3039C, V3285I, or H3311R mutation. Minigenes that encode such PKD1 polypeptides can be synthesized and/or engineered using the PKD1 polynucleotide sequence (SEQ ID NO:1).

[0217] The materials for use in the assay of the invention are ideally suited for the preparation of a kit. Such a kit can comprise a carrier means containing one or more container means such as vials, tubes, and the like, each of the container means comprising one of the separate elements to be used in the method. One of the container means can comprise a probe that is or can be detectably labeled. Such probe can be an oligonucleotide comprising at least 10 contiguous nucleotides and having a sequence of a fragment of SEQ ID NO:1 including: nucleotide 474, wherein nucleotide 474 is a T; nucleotide 487, wherein nucleotide 487 is an A; nucleotide 3110, wherein nucleotide 3110 is a C; nucleotide 8298, wherein nucleotide 8298 is a G; nucleotide 9164, wherein nucleotide 9164 is a G; nucleotide 9213, wherein nucleotide 9213 is an A; nucleotide 9326, wherein nucleotide 9326 is a T; nucleotide 9367, wherein nucleotide 9367 is a T; nucleotide 10064, wherein nucleotide 10064 is an A; nucleotide 10143, wherein nucleotide 10143 is a G; nucleotide 10234, wherein nucleotide 10234 is a C; or nucleotide 10255, wherein nucleotide 10255 is a T (see, also, Example 2).

[0218] A kit containing one or more oligonucleotide probes of the invention can be useful, for example, for qualitatively identifying the presence of mutant PKD1 polynucleotide sequences in a sample, as well as for quantifying the degree of binding of the probe for determining the occurrence of specific strongly binding (hybridizing) sequences, thus indicating the likelihood for a subject having or predisposed to a disorder associated with PKD1. Where the kit utilizes nucleic

acid hybridization to detect the target nucleic acid, the kit can also have containers containing reagents for amplification of the target nucleic acid sequence. When it is desirable to amplify the mutant target sequence, this can be accomplished using oligonucleotide primers, which are based upon identification of the flanking regions contiguous with the target nucleotide sequence. For example, primers such as those listed below in Tables 1 and 2 can be included in the kits of the invention. The kit can also contain a container comprising a reporter means such as an enzymatic, fluorescent, or radionuclide label, which can be bound to or incorporated into the oligonucleotide and can facilitate identification of the oligonucleotide.

[0219] The following examples are intended to illustrate but not limit the invention.

EXAMPLES

[0220] The present invention is based upon the use of widely spaced PKD1-specific anchor primers in long range PCR to generate 5 kb to 10 kb PKD1 polynucleotide segments. After appropriate dilution, the PCR products can be used as a template for mutation screening using any one of a variety of methods. Accordingly, a number of mutants have been identified in families with PKD1-associated disorders.

[0221] Using a number of PKD1-specific primers, eight templates ranging in size from about 0.3 to 5.8 kb were generated that span from the 5' untranslated region to intron 34 and cover all exons in the replicated region including exon 1 and exon 22 (Example 1). These reagents were used to evaluate 47 Asian PKD1 families (Example 2). Variant nucleotide sequences were found throughout the PKD1 polynucleotide sequence.

[0222] Forty-one Thai and 6 Korean ADPKD families were studied. Samples from 50 healthy Thai blood donors collected in blood banks served as normal controls. Genomic DNA was extracted from either fresh or frozen whole blood

that had been stored for up to five years using commercially available kits (Puregene, Gentra) or standard phenol-chloroform methods. For the N23HA and 145.19 cell lines (Cell 77:881-894, 1994; Germino *et al.*, Am J. Hum. Genet. 46:925-933, 1990; Ceccherini *et al.*, Proc. Natl. Acad. Sci. USA 89:104-108, 1992, each of which is incorporated herein by reference; see, also, Watnick et al., *supra*, 1997), genomic DNA was isolated using the Puregene DNA isolation kit.

LONG RANGE SPECIFIC TEMPLATES

[0223] A two-part strategy was used to generate and validate PKD1-specific primers that could be used to amplify the replicated portion of PKD1. The sequence of PKD1 (SEQ ID NO:1) was aligned with that of two homologues present in GenBank (Accession Number AC002039) and identified potential sequence differences. Candidate primers were designed such that the mismatches were positioned at or adjacent to the 3' end of the oligonucleotide so as to maximize their specificity for PKD1.

[0224] The primers were tested for specificity using rodent-human somatic cell hybrids that either contained only human 16p13.3 and therefore, human PKD1 (145.19, a radiation hybrid), or that lacked 16p13.3 and contained only the human PKD1-homologues (N23HA). Figure 2 presents a representative example of this approach using the primer pair, BPF6 and the PKD1-specific primer BPR6. This primer pair amplified a product of the correct length (4.5 kb) under the stated conditions only when total human genomic DNA or 145.19 DNA is used as template. Similar results were obtained when BPR6 was used in combination with the non-specific primer 28F to generate a much shorter product.

[0225] As a final control, the absence of amplified product was verified using N23HA as template to confirm that the results obtained using total human genomic DNA and 145.19 DNA were due to the specificity of the primer and not the result of other causes (*i.e.*, difference in quality of DNA or ratio of human/rodent template). A primer specific for the homologues (BPR6HG) was

designed that was positioned the same distance from BPF6 as BPR6 and used to amplify a specific band of the same size as the corresponding PKD1-long range product. As predicted, a product of the correct size was amplified from both N23HA and total genomic DNA, but not from 145.19.

[0226] A total of eight primer pairs can be used to generate a series of templates that range in size from about 0.3kb to 5.8kb and include all exons and their flanking intron sequences in the replicated portion of PKD1 (exons 1 to 34). Table 1 summarizes the details for each product and includes the sequence of each primer, its respective position within the gene, its expected size, and the optimal annealing temperature and extension time for its amplification. Figure 1 illustrates the relative position of each product with respect to the overall gene structure. It should be noted that exon 1 and its flanking sequences were particularly problematic to evaluate. Primer design was greatly limited by the high degree of homology and extreme GC bias in the region. A combination of widely space primers (to generate a fragment considerably larger than the segment of interest) and the GC melt system were used to circumvent these obstacles.

[0227] Specific details concerning the primer sequences, annealing temperatures and extension times used for each long-range (LR) template are provided in Table 1 (all sequences in Tables 1 and 2 are shown in 5' to 3' orientation from left to right). Three hundred to 400 ng of genomic DNA was used as template for each LR product, except for exon 1 (see below). The long range PCR amplification was performed as follows in a Perkin Elmer 9600 thermal cycler: denaturation at 95°C for 3 min followed by 35 cycles of a two-step protocol that included denaturation at 95°C for 20 sec followed by annealing and extension at a temperature and for a time specific for each primer pair (Table 1). A final extension at 72°C for 10 min was included in each program. The total PCR volume was 50 µl using 4 U of *rTth* DNA polymerase XL (Cetus, Perkin Elmer) and a final MgOAC₂ concentration of 0.9 mM. A hot start protocol as

Table 1

Oligonucleotide primers for Long-range specific templates
from exon 1-34 of PKD1 gene

Template	Primers	Sequence 5'→3'	Position (5')	Size (kb)	T _m (°C)	ET (Min)	SEQ ID NO:
T1	BPF14*	CCATCCACCTGCTGTGTGAC CTGGTAAAT	2043	2.2	69	7	3
	BPR9	CCACCTCATCGCCCCCTTCCT AAGCAT	4290				4
T2-7	BPF9*	ATTTTTTGAGATGGAGCTTC ACTCTTGCAGG	17907	4.6	68	7	5
	BPR4	CGCTCGGCAGGCCCTAACC	22489				6
T8-12	BPF12	CCGCCCCCAGGAGCCTAGAC G	22218	4.2	68	7	7
	BPR5*	CATCCTGTTCATCCGCTCCA CGGTAC	26363				8
T13-15	F13	TGGAGGGAGGGACGCCAAT C	26246	4.4	68	7	9
	R27*	GTCAACGTGGGCCTCCAAGT	30612				10
T15-21	F26*	AGCGCAACTACTTGGAGGCC C	30603	3.4	70	4.5	11
	R2	GCAGGGTGAGCAGGTGGGG CCATCCTAC	33953				12
T22	BPF15	GAGGCTGTGGGGTCCAGTC AAGTGG	36815	0.3	72	1	13
	BPR12*	AGGGAGGCAGAGGAAAGGG CCGAAC	37136				14
T23-28	BPF6	CCCCGTCCTCCCCGTCCTTTT GTC	37325	4.2	69	7	15
	BPR6*	AAGCGCAAAAGGGCTGCGT CG	41524				16
T29-34	BPF13*	GGCCCTCCCTGCCTTCTAGG CG	41504	5.8	68	8	17
	KG8R25*	GTTGCAGCCAAGCCCATGTT A	47316				18

T_m - annealing temperature; ET – extension time; * - PKD1-specific primer.

Bold type in BPR12 primer sequence identifies intentional replacement of C by A to enhance discrimination of PKD1 from homologs.

recommended by the manufacturer was used for the first cycle of amplification.

For the exon 1 LR product (T1), the LR was generated using 500 ng of genomic DNA. The long range PCR amplification was modified as follows: denaturation 95°C for 1 min followed by 35 two-step cycles of denaturation at 95°C for 30 sec

followed by annealing and extension at 69°C for 7 min. The total PCR volume was 50 µl using 1 µl of Advantage-GC genomic polymerase (Clontech), GC melt of 1.5 M and final MgOAC₂ concentration of 1.1 mM.

[0228] The long-range templates were serially diluted (1:10⁴ or 1:10⁵) to remove genomic contamination, then used as templates for nested PCR of 200-400 bp exonic fragments. A total of 17 new primer pairs were developed for exons 1-12 and exon 22. The sequences and PCR conditions for each new pair are summarized in Table 2. Primer sequences and PCR conditions for exons 13-21 and 23-34 are described in Watnick *et al.*, Am. J. Hum. Genet. 65:1561-1571, 1999; and Watnick *et al.*, Hum. Mol. Genet. 6:1473-1481, 1997, which are incorporated herein by reference. Intron based primers were positioned approximately 30-50 bp away from consensus splice sites. Exons larger than approximately 400 bp were split into overlapping fragments of less than or equal to 350 bp. Two µl of diluted long range (LR) product was used as template for amplification of each exon. Single strand conformation analysis was performed using standard protocols. SSCA analysis was performed by use of 8% polyacrylamide gels with 5% glycerol added. The radiolabeled PCR products were diluted with loading buffer, were denatured by heating at 95°C for 5 min, then were placed on ice prior to being loaded and run on the gel at room temperature. Gels were run at 400 V overnight, dried, and placed on X-Omat XAR film (Kodak) at room temperature. Aberrantly migrating bands detected by SSCA were cut from the gel and eluted into 100 µl of sterile water overnight. The eluted products were re-amplified using the same set of primers, purified using Centricon-100 columns (Amicon) and then sequenced.

Table 2

Nested Primers Used for Mutation Detection

Exons	Primer	Primer Sequence 5' 3'	Fragment size (bp)	T _m (°C)	SEQ ID NO:
T1	1F1	GGTCGCGCTGTGGCGAAGG	328	67	19
T1	1R1	CGGCGGGCGGCATCGT			20
T1	1F2	ACGGCGGGGCCATGCG	348	67	21
T1	1R2	GCGTCCTGGCCCCGCTCC			22
T2-7	2F	TTGGGGATGCTGGCAATGTG	272	62	23
T2-7	2R	GGGATTCGGCAAAGCTGATG			24
T2-7	3F	CCATCAGCTTTGCCGAATCC	171	62	25
T2-7	3R	AGGGCAGAAGGGATATTGGG			26
T2-7	4F	AGACCCTTCCCACCAGACCT	299	62	27
T2-7	4R	TGAGCCCTGCCCAGTGTCT			28
T2-7	5F1	GAGCCAGGAGGAGCAGAACC C	259	65	29
T2-7	5R1	AGAGGGACAGGCAGGCAAA GG			30
T2-7	5F2	CCCAGCCCTCCAGTGCCCT	284	65	31
T2-7	5R2	CCCAGGCAGCACATAGCGAT			32
T2-7	5F3	CCGAGGTGGATGCCGCTG	294	65	33
T2-7	5R3	GAAGGGGAGTGGGCAGCAGA C			34
T2-7	6F	CACTGACCGTTGACACCCTCG	281	65	35
T2-7	6R	TGCCCCAGTGCTTCAGAGATC			36
T2-7	7F	GGAGTGCCCTGAGCCCCCT	311	65	37
T2-7	7R	CCCCTAACCACAGCCAGCG			38
T8-12	8F	TCTGTTCGTCCTGGTGTCTG	215	65	39
T8-12	8R	GCAGGAGGGCAGGTTGTAGA A			40
T8-12	9F	GGTAGGGGGAGTCTGGGCTT	253	65	41
T8-12	9R	GAGGCCACCCCGAGTCC			42
T8-12	10F	GTTGGGCATCTCTGACGGTG	364	65	43
T8-12	10R	GGAAGGTGGCCTGAGGAGAT			44
T8-12	11F2	GGGGTCCACGGGCCATG	311	67	45
T8-12	11R2	AAGCCCAGCAGCACGGTGAG			46
T8-12	11midF	GCTTGCAGCCACGGAAC	386	65	47
T8-12	11midR	GCAGTGCTACCACTGAGAAC			48
T8-12	11F1	TGCCCCTGGGAGACCAACGA TAC	303	67	49
T8-12	11R1	GGCTGCTGCCCTCACTGGGA AG			50

TABLE 2 (cont.)

Exons	Primer	Sequence 5' 3'	Fragment size (bp)	T _m (°C)	SEQ ID NO:
12	12F	GAGGCGACAGGCTAAGGG	286	64	51
	12R-2	CATGAAGCAGAGCAGAAGG			61
13	13F:	TGGAGGGAGGGACGCCAATC	308	67	62
	13R:	GAGGCTGGGGCTGGGACAA			63
14	14F:	CCCGGTTCACTCACTGCG	220	64	64
	14R:	CCGTGCTCAGAGCCTGAAAG			65
15	15F16:	CGGGTGGGGAGCAGGTGG	280	67	66
	15R16:	GCTCTGGGTGAGGACAGGGG A			67
15	15F15:	CGCCTGGGGGTGTTCTTT	270	64	68
	15R15:	ACGTGATGTTGTCGCCCCG			69
15	15F14:	GCCCCGTGGTGGTCAGC	250	67	70
	15R14:	CAGGCTGCGTGGGGATGC			71
15	15F13:	CTGGAGGTGCTGCGCGTT	256	67	72
	15R13:	CTGGCTCCACGCAGATGC			73
15	15F12:	CGTGAACAGGGCGCATTA	270	65	74
	15R12:	GCAGCAGAGATGTTGTTGGA C			75
15	15F11:	CCAGGCTCCTATCTTGTGACA	259	60	76
	15R11:	TGAAGTCACCTGTGCTGTTGT			77
15	15F10:	CTACCTGTGGGATCTGGGG	217	67	78
	15R10:	TGCTGAAGCTCACGCTCC			79
15	15F9:	GGGCTCGTCGTCAATGCAAG	267	67	80
	15R9:	CACCACCTGCAGCCCCTCTA			81
15	15F8:	5CCGCCCAGGACAGCATCTTC	261	64	82
	15R8:	CGCTGCCCAGCATGTTGG			83
15	15F7:	CGGCAAAGGCTTCTCGCTC	288	64	84
	15R7:	CCGGGTGTGGGGAAGCTATG			85
15	15F6:	CGAGCCATTTACCACCCATA G	231	65	86
	15R6:	GCCCAGCACGAGCTCACAT			87
15	15F5:	CCACGGGCACCAATGTGAG	251	64	88
	15R5:	GGCAGCCAGCAGGATCTGAA			89
15	15F4:	CAGCAGCAAGGTGGTGGC	333	67	90
	15R4:	GCGTAGGCGACCCGAGAG			91
15	15F3:	ACGGGCACTGAGAGGAACTT C	206	64	92
	15R3:	ACCAGCGTGCGTTCTCACT			93
15	15F2:	GCCGCGACGTCACCTACAC	265	67	94
	15R2:	TCGGCCCTGGGCTCATCT			95
15	15F1:	GTCGCCAGGGCAGGACACAG	228	68	96
	R27:	AGGTCAACGTGGGCCTCCAA			113
15	15F1-1:	ACTTGGAGGCCACGTTGAC C	276	69	97
	15R1-1:	TGATGGGCACCAGGCGCTC			98
15	15F1-2:	CATCCAGGCCAATGTGACGG T	266	64	99
	15R1-2:	CCTGGTGGCAAGCTGGGTGT T			100
16	16F:	TAAAACTGGATGGGGCTCTC	294	56	101
	16R:	GGCCTCCACCAGCACTAA			102

TABLE 2 (cont.)

Exons	Primers	Primer Sequence 5'-3'	Fragment size (bp)	T _m (°C)	SEQ ID NO:
17	17F:	GGGTCCCCCAGTCCTTCCAG	244	67	103
	17R:	TCCCCAGCCCCGCCACA			104
18	18F:	GCCCCCTCACCACCCCTTCT	342	67	105
	18R:	TCCCGCTGCTCCCCCCAC			106
19	19F:	GATGCCGTGGGGACCGTC	285	67	107
	19R:	GTGAGCAGGTGGCAGTCTCG			108
20	20F:	CCACCCCCTCTGCTCGTAGGT	232	64	109
	20R:	GGTCCCAAGCACGCATGCA			110
21	21F:	TGCCGGCCTCCTGCGCTGCTG A	232	67	111
	TWR2-1:	GTAGGATGGCCCCACCTGCT CACCCTGC			112

[0229] Variants that were predicted to alter a restriction site were confirmed by restriction enzyme digestion analysis of re-amplified products. In cases where the change did not alter a restriction site, primers were designed with mismatches that create a new restriction site when combined with the point mutation in question.

The following primer combinations were utilized:

ASP1+26R (ASP1; 5'-CTGGTGACCTACATGGTCATGGCC GAGATC-3'; SEQ ID NO:55);

ASP2+30R (ASP2; 5'-GGTTGTCTATCCCGTCTACCTGGCCCTCCT-3'; SEQ ID NO:56);

ASP3 + 30F (ASP3; 5'-GTCCCCAGCCCCAGCCCACCTGGCC-3'; SEQ ID NO:57).

[0230] When possible, segregation of the variant with the disease phenotype was tested. In cases where a missense change was unable to be determined on the normal haplotype (and thus be a normal variant) the mutation was tested for in a panel of 50 normal controls.

MUTATION SCREENING

[0232] A total of 13 novel variants were detected by SSCA using the conditions described above. Two are highly likely to be pathogenic mutations, four are predicted to encode missense substitutions not found in normals and seven are normal variants (see Table 3).

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Table 3
Mutations Identified in the PKD1 Gene in a Thai population

Patient	Exon	Nucleic Acid Change	Codon Change	Consequence	Confirmation Enzyme
Pathogenic					
<i>RAMA28-01</i> ⁰	12	T3110C	W967R	Missense (disrupt PKD domain3)	<i>BsaW</i> I (cut NC)
<i>RAMA59-02</i> *	25	G9213A	W3001X	Nonsense (early termination)	<i>Mae</i> I
Variants not found in 100 chromosomes					
<i>RAMA3-02</i> *	22	T8298G	L2696R	Missense	<i>HinP1</i> I
<i>RAMA87-01</i> *	25	A9164G	R2985G	Missense	<i>BsrB</i> I
<i>RAMA87-01</i> *	25	C9326T	R3039C	Missense	<i>Fau</i> I (cut NC)
<i>RAMA45-03</i> *	29	G10064A	V3285I	Missense	<i>Bsm</i> I
Probable normal variants					
<i>RAMA7-06</i>	2	C474T	A88V	Missense	<i>Hph</i> I
<i>RAMA107-01</i>	2	G487A	A92A	Silent change	<i>TspR</i> I
<i>RAMA94-01</i>	25	C9367T	G3052G	Silent change	<i>Sfo</i> I (cut NC)
<i>RAMA66-01</i>	30	A10143G ^{HG}	H3311R	Missense	<i>Nsp</i> I (cut NC)
<i>RAMA66-01</i>	30	T10234C ^{HG}	L3341L	Silent change	ASP1 + <i>BseR</i> I
<i>RAMA51-01</i>	30	G10255T	R3348R	Silent change	ASP2 + <i>MSC</i> I

* - Segregation with disease; 0 - cannot test for segregation; NC - Normal control;

HG - Present in one copy of the homologues; ASP - Allele-specific primer.

[0234] These pathogenic mutations add to previously identified pathogenic mutations, including a deletion of G3336 (Δ G3336) in exon 13, resulting in a frame shift after amino acid 1041 (FS1041); C4168T (Q1653X), C6089T (Q1960X) and C6326T (Q2039X) mutations in exon 15, each resulting in a nonsense termination; Δ G7205-G7211 in exon 16, resulting in a FS2331; a C7415T (R2402X) mutation in exon 18, resulting in a nonsense termination; a C7883T (Q2558X) mutation in exon 19, resulting in a nonsense termination; and a Δ C8159-T8160 mutation in exon 21, resulting in a FS2649 (Phakdeekitcharoen et al., *supra*, 2000). In addition, probable pathogenic mutations including G3707A (G1166S) and T6078A (V1956E) missense mutations in exon 15, and

a C7433T (R2408C) missense mutation and an insertion of a GCG trinucleotide between G7535 and G7536 (extra Gly2422) in exon 18 have been identified (Phakdeekitcharoen et al., *supra*, 2000).

[0235] Four additional mutations unique to one of the families also were identified (see Table 3). The mutants segregate with disease, and were not observed in a screen of over 100 normal Thai chromosomes. Three of the four variants are predicted to result in non-conservative amino acid substitutions. Two of them (A9164G, C9326T) are present in the same allele of a single family (RAMA87). As such, these mutations meet several criteria expected of disease-producing mutations, including they are not found in normal, ethnically matched chromosomes, they segregate with the disease, and they result in non-conservative substitutions.

[0236] In one case a heteroduplex pattern was discovered for the exon 22 product of the proband by standard agarose electrophoresis. The heteroduplex pattern was confirmed to segregate with disease and subsequently determined that the novel variant was the result of a T to G transversion at position 8298. This mutation is predicted to substitute arginine for leucine at position 2696 of the protein sequence. This non-conservative substitution is within the REJ domain. Interestingly, the R3039C substitution occurs near a newly described putative proteolytic cleavage site of polycystin-1, His(3047)-Leu-Thr-Ala(3050) (SEQ ID NO:59). In the corresponding position of *Fugu* and murine polycystin-1, glutamic acid and arginine, respectively, are present, suggesting a non-critical role for a non-polar residue at this location.

[0237] Seven nucleotide substitutions that are likely normal variants were also identified. Two are missense variants that do not segregate with disease in the family in which they were discovered. The C474T substitution results in the conservative replacement of valine by alanine at position 88 in the first leucine rich (LRR) repeat. The amino acid is not conserved between species and is not predicted to disrupt the LRR structure. The second missense variant, A10143G,

substitutes arginine for histidine at position 3311 within the first extracellular loop between TM2 and TM3. It too, is a conservative change involving a residue whose identity is not evolutionarily conserved at this position. The other five variants were silent nucleotide substitutions that were unique to the pedigree in which they were found and not found in more than 100 normal chromosomes. It is possible that these variants can be pathogenic by affecting gene splicing in the region. Two of the normal variants of exon 30, A10143G (H3311R) and T10234C (L3341L), were clustered together in a single PKD1 haplotype. Interestingly, both variants also are present in at least one of the homologues, suggesting a previous gene conversion event as the original of these PKD1 variants. Additional PKD1 variants, which do not appear to be associated with a PKD1-associated disorder, include two silent mutations, G4885A (T1558T) and C6058T (S1949S), and a missense mutation, G6195A (R1995H), in exon 15; a silent T7376C (L2389L) mutation in exon 17; a silent C7696T (C2495C) mutation in exon 18; and a missense G8021A (D2604N) mutation in exon 20 (Phakdeekitcharoen et al., *supra*, 2000).

[0238] Table 4 summarizes the clinical findings for the probands of 17 Thai families. The genotypes and phenotypes for patients with ADPKD are shown. It has been estimated on the basis of studies of Caucasian populations that approximately 15% of mutations are localized to the nonreplicated portion of the PKD1 gene. If the same frequency is true for the Thai population (the patients were not screened for mutations in the nonreiterated portion), then the present studies have identified approximately 45% to 54 percent of all mutations present in the nonreplicated region. This detection rate likely can be increased by using more sensitive detection methods such as DHPLC (Kristensen et al., *supra*, 2001), HTCSGD (Leung et al., *supra*, 2001), or the like.

Table 4
Genotypes and phenotypes in Thai ADPKD1

Patients	Age	Genotype		HT	Consequence	Renal insuff. (Cr>2)	Renal stone	Palpable kidneys	Liver Cyst	Phenotype		Ref.
		Exon	Codon Change							Heart Valv. Abnorm.	Brain Aneur.	
RAMA28-0	30	12	W967R	+	Missense	-	-	-	-	-	-	
RAMA103-	57	13	FS after 1041	+	Frameshift	-	+	-	+	-	-	(*)
RAMA49-0	26	15	G1166S	+	Missense	-	-	+	-	-	-	(*)
RAMA36-0	47	15	Q1653X	+	Nonsense	-	-	+	-	-	-	(*)
RAMA108-	57	15	V1956E	+	Missense	+	-	-	-	-	-	(*)
RAMA77-0	53	15	Q1960X	+	Nonsense	+	-	+	+	-	-	(*)
RAMA32-0	36	15	Q2039X	+	Nonsense	+	-	+	-	-	-	(*)
RAMA97-0	45	17	R2402X	+	Nonsense	+	-	-	-	-	-	(*)
RAMA96-0	30	18	R2408C	-	Missense	-	+	-	+	-	-	(*)
RAMA99-0	56	18	R2430X	+	Nonsense	+	+	-	+	-	-	(*)
RAMA66-0	39	18	2442 add'l. Gly	+	Extra Glycine	-	+	-	-	-	-	(*)
RAMA55-0	52	19	Q2558X	-	Nonsense	-	-	+	+	-	-	(*)
RAMA5-01	53	21	FS after 2649	+	Frameshift	+	+	+	+	+	+	(*)
RAMA3-02	40	22	L2696R	+	Missense	+	-	+	+	-	-	
RAMA87-0	61	25	R2985G	-	Missense	-	-	+	+	-	-	
	25		R3039C		Missense							
RAMA59-0	35	25	W3001X	+	Nonsense	+	+	-	-	-	-	
RAMA45-0	59	29	V3285I	+	Missense	+	-	-	-	-	-	

HT - hypertension; Renal insuff. - renal insufficiency; Heart Valv. Abnorm. - heart valvular abnormalities; Brain Aneur. - brain aneurisym; * - Phakdeekitcharoen et al., *supra*, 2000.

[0239] Although the invention has been described with reference to the above examples, it will be understood that modifications and variations are encompassed within the spirit and scope of the invention. Accordingly, the invention is limited only by the following claims.

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